Developing a spatially-explicit climate adaptation framework for estuarine ecosystems of the San Francisco Bay:

Climate Adaptation for Decision Support (CADS Phase 1)

Original funded project title: Structured-Decision Making for Climate Change Adaptation to Conserve San Francisco Bay Tidal Marsh Ecosystems

Final Report to the California Landscape Conservation Cooperative (funding agency for CADS Phase 1), and interim report to the US Fish & Wildlife Service National Wildlife Refuge System Inventory and Monitoring Initiative.

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Preface

This report provides recommended resource allocations for conserving four subregions of San Francisco (SF) Bay, including North Bay, Suisun, Central Bay and South Bay. These recommendations are based on quantitative, subregional decision tools that were developed in collaboration with stakeholders working in each subregion. The authors of this report would like to thank all the participants, including the leadership team and other stakeholders that included natural resource managers and planners working in SF Bay. Without this dedicated set of individuals, this project would not have been possible and the products of the project are intended for the stakeholders of SF Bay.

The scope of recommended resource allocations are within the Baylands that surround and include the SF Bay Estuary. The project defines four estuarine ecosystems from low to higher elevation: subtidal and intertidal mudflats, tidal marsh, managed wetlands, and upland transition zone. We also define two upland ecosystems within the Baylands where actions can be taken for conserving the Estuary: migration space (adjacent uplands) and watersheds feeding the Estuary.

The report is primarily written for stakeholders and scientists working toward conservation of the SF Bay Estuary. It may also be informative for those working on multi-scale conservation efforts in other geographic regions, or for those who are interested in broad-extent conservation planning and decision analysis.

How to use this report

The 'Detailed Summary' is the main entry point for almost every reader of this report. It provides a digest of the motivation for the project, Bayland-wide framework, and products for informing conservation of the SF Bay Estuary.

The body of the report is broken into 7 chapters:

Chapter 1:	Impetus and motivation for the CADS project.
Chapter 2:	Overview of the project along with a summary of the stakeholder engagement.
Chapter 3:	Description of bayland-wide products. These products informed development of subregional decision tools. This chapter is most relevant for those who want a better understanding of the basis from which the subregion-specific products were developed.
Chapter 4:	Further details on how Bayland-wide products were developed, with particular emphasis on stakeholder involvement.
Chapter 5:	Description of subregional decision tools and is targeted more toward on-ground decision makers and stakeholders working in a particular subregion.
Chapter 6:	Synthesis of findings from each of the four subregional decision tools and ideas for extending the CADS approach to include tradeoffs between subregional-level and regional-level objectives.
Chapter 7:	Looks back at what we learned through CADS Phase 1 and provides thoughts on how future conservation planning processes can be more successful within and beyond SF Bay.

Detailed summary

This report provides recommended resource allocations for conserving natural resources in four subregions of San Francisco (SF) Bay, including North Bay, Suisun, Central Bay and South Bay. These recommendations are based on quantitative, subregional decision tools that were developed in collaboration with stakeholders working in each subregion. The overarching conservation objective to be achieved and supported through the decision tools and recommendations for the subregions was:

Perpetuate the physical integrity, functions, biodiversity, and wild populations of estuarine ecosystems, while meeting demands for human health, safety, and well-being.

To achieve this objective, we identified a recommendation that was consistent among subregions and remained the same even when changing assumptions about external drivers including extreme weather events and availability of resources (funding, staff, and equipment for conservation actions).

We found that the recommendation for all subregions was to allocate resources in a way that assumes a rosy future for external environmental conditions (including sea level rise and extreme storms) and for availability of resources. Stakeholders were on average more optimistic about the effectiveness of allocation options, over the near-term and long-term, that assume a rosy future even if the future turns out to be not so great in terms of the external drivers (e.g., sediment, storms, sea level rise, funding). In other words, stakeholders believed the assume-rosy allocation in each subregion to be robust to worse-case scenarios for the external drivers.

This detailed summary is a digest of the motivation for the project, Bayland-wide framework, and products for informing conservation of the SF Bay Estuary.

Motivation

Uncertainties about future sea-level rise, intensity and frequency of extreme weather events, along with human development pressures and availability of funding and other resources to implement conservation actions present a daunting problem for stakeholders concerned about the ecosystem integrity of the SF Bay Estuary. This has brought about a great need for consistently agreed-upon conservation objectives in the Estuary against which to make management decisions and measure conservation effectiveness. In particular, resource managers are asking for expertly-vetted recommendations for allocating limited resources toward accomplishing the identified conservation objectives in the Estuary.

A workshop sponsored by the California Landscape Conservation Cooperative was held in October 2011, during which stakeholders and scientists identified a recommendation to increase investment in climate adaptation actions to conserve tidal marshes of SF Bay rather than the status quo strategy that takes minimal consideration of future climate-change impacts (Thorne et al. 2015). Since 2012, the Bayland Ecosystem Habitat Goals Update (BEHGU) has been developing a list of recommended goals and actions at multiple spatial scales that address projected climate change impacts for conservation within each ecosystem of the Baylands that include SF Bay. BEHGU recommendations are meant to accommodate future climate scenarios, but there is no underlying decision process or tool to justify the ultimate selection of recommendations (from a set of candidate recommendations) nor are the recommendations specified for particular time periods or resource availability scenarios. This called for an evaluation of how alternative ways of allocating resources among BEHGU-recommended actions would be expected to perform, so that more actionable and defensible recommendations could be identified that explicitly account for uncertainties regarding management outcomes and effects of external drivers that are beyond the control of management (e.g., climate change, resource availability).

Recommendations from the 2011 workshop combined with knowledge gaps revealed through BEHGU led to six main challenges:

1) Engage a broader suite of stakeholders and experts engaged in conservation of SF Bay.
2) Account for subregional differences with regard to the costs and constraints of taking climate-adaptation actions, suites of conservation objectives, and uncertainties regarding management effectiveness, sediment dynamics, and climate-change impacts.
3) Address the linked nature of decisions, objectives and outcomes across time and space. Decisions about project-level actions taken in the near future should account for the consequences of actions taken in the more distant future. Likewise, decisions should account for project-level actions scaling up to influence the subregional and regional-level objectives.
4) Incorporate additional system components, including habitat types (e.g. tidal flats, low marsh, mid-marsh, high-marsh, upland transition, managed ponds) and species of conservation concern with contrasting requirements compared to Ridgway's Rail (e.g., salt marsh harvest mouse, shorebirds). Consider especially tradeoffs with respect to contrasting responses of multiple species/communities and associated transitions of spatial elements from one estuarine environment type to another.
5) Consider a broader response horizon going out to 2100 to bring in the full range of uncertainty about future sea-level rise.
6) Inform design of an adaptive management and monitoring program that guides and evaluates management actions by addressing key sources of uncertainty with high value of information.

In response to these six challenges the CADS (Climate Adaptation Decision Support for SF Bay) project was undertaken by the San Francisco Bay Joint Venture, a collaborative partnership for the protection, restoration, and enhancement of all types of wetlands for the benefit of birds, other wildlife, and people. CADS was an answer to a call from managers to measure the impacts of conservation actions on a landscape level while helping ensure that current conservation and management actions optimize the potential to address climate change in an era of limited resources. During each step of the project, over 25 stakeholders were engaged to ensure that the recommendations and products from this project would be defensible and useable by on-ground decision-makers. We define a stakeholder as an entity who has direct influence or is influenced by a particular decision or set of decisions for conservation in SF Bay.

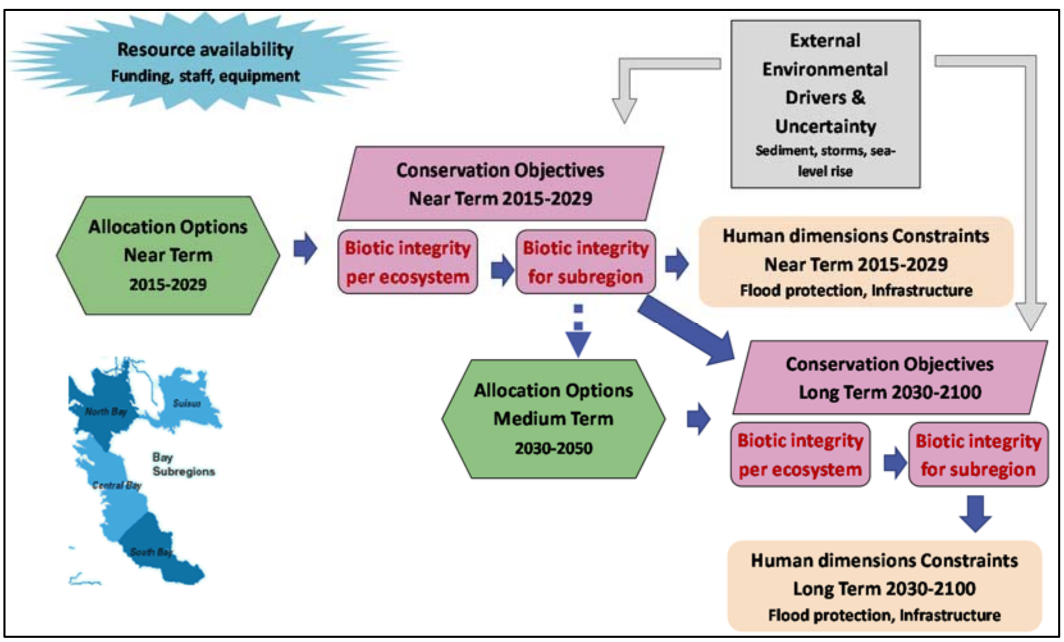
The project is divided into two phases, with Phase 1 focused on establishing regional and subregional conservation objectives leading to recommended resource allocations for each of the four subregions in SF Bay (North Bay, Suisun, Central Bay, and South Bay). Phase 2 will demonstrate how subregional recommendations can inform local-scale climate adaptation strategies. In particular, climate adaption recommendations for the North Bay subregion (from Phase 1) will be used to inform development of the San Pablo Bay National Wildlife Refuge climate adaptation plan (in Phase 2). This report describes the set-up and findings from CADS Phase 1 (henceforth, CADS).

Bayland-wide framework for conserving the SF Bay Estuary

A major first step of the project was agreeing on the type of decision (e.g., discrete choices or resource allocation) and which spatial and temporal scales to be address through CADS. These products provided a framework for developing a decision tool for each subregion of the SF Bay. In the context of the conservation problem in the SF Bay Estuary, we developed a concise question that summarizes the essential elements of the decision to be made as a decision question:

How should limited resources be allocated across time and space toward potential actions within subregions to conserve San Francisco Bay estuarine ecosystems while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?

In particular, we wanted to identify a resource allocation for a near-term (2015-2029) and a longer-term (2030-2050) management time horizon to achieve conservation objectives over two outcome horizons, including the near-term (2015-2029) and the long-term (2030-2100). These time horizons were chosen to remain consistent with the BEHGU.



Conceptual diagram representing resource allocation decisions in SF Bay

For developing conservation objectives and recommendations to achieve them, we classified the Baylands surrounding SF Bay into six ecosystem classes that were also consistent with the BEHGU:

Estuarine ecosystems

1) **Sub-tidal and intertidal mudflats**

Estuarine subtidal: Those estuarine ecosystems within substrate that is permanently flooded by tidal water

Estuarine intertidal mudflats: Sedimentary intertidal habitats created by deposition in low energy coastal environments, particularly estuaries and other sheltered areas. Their sediment consists mostly of silts and clays with a high organic content.

2) **Tidal marsh**

Marsh found in estuaries where the flooding characteristics are determined by the tidal movement of the adjacent estuary, sea or ocean. According to the salinity of the flooding water, freshwater, brackish and saline tidal marshes are distinguished. Respectively, they may be classified into coastal marshes and estuarine marshes. They are also commonly zoned into lower marshes (also called intertidal marshes) and upper or high marshes, based on their elevation with respect to the sea level. They may be classified by salinity, tide range, and geomorphic setting.

3) **Managed/diked marsh and ponds**

Diked marshes and managed ponds (e.g., former salt production ponds) are generally managed by owners to provide habitat for waterfowl, shorebirds, and other water birds. Primary management strategies usually involve the manipulation of salinity (from more salty to less salty), the regulation of water levels (draining and flooding). Management of water quality and quantity require regular maintenance of infrastructure (e.g., levees/dikes, water control structures). The intensity of management can have a significant effect on the plants and animals inhabiting managed ponds and marsh.

4) **Upland transition zone**

Estuarine-terrestrial transition zones occupy the boundary between land and sea, from tidal marsh up to the effective limit of tidal influence. These zones harbor unique plant communities, provide critical wildlife support to adjacent ecosystems, and play an important role in linking marine and terrestrial processes. Includes seasonal wetlands (areas where water covers the soil only during the wet season) and vernal pools.

Non-estuarine, upland ecosystems

5) **Migration space**

Includes agricultural lands adjacent to Baylands (primarily found in North Bay) along with upland areas adjacent to any of the estuarine ecosystems. To be considered migration space, the adjacent uplands must have sufficient slope and elevation that would provide some possibility for the upland ecosystem to transition into an estuarine ecosystem with sea-level rise.

6) **Watershed**

A drainage basin or watershed is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join the estuary.

Components of subregional decision tools

In addition to providing management recommendations and stemming from the 2011 Bayland-wide framework for conservation, there were several other important products developed in this project when developing the subregional decision tools. Each decision tool was comprised of measurable conservation objectives that were linked to action categories and external drivers (e.g., resource availability, extreme storms). The decision tools also took into account scenarios for future uncertainties about the external drivers.

Conservation objectives

For each ecosystem, the teams defined an overarching conservation objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) and long-term (2030-2100) outcome horizons. Subregional teams were aware of many possible indicators that could be used to represent the biotic integrity of each estuarine ecosystem, but they chose a subset to ensure their decision tools would be tractable to complete and so they could identify recommended allocation options during the lifespan of this project. Indicators were also chosen to represent the most important desired conservation outcomes for stakeholders in each ecosystem. Birds were the most commonly chosen indicators among subregions, followed by plants, fish, and indicators that integrate disparate attributes of the ecosystem. Most often chosen bird guilds were ducks and shorebirds. Less frequently chosen indicators were mammals, physical attributes, shellfish, and herpetofauna. Selection of particular indicator species or ecosystem attributes varied widely among subregions for any given ecosystem. Only three indicators were chosen for multiple subregions: subtidal acreage with native living substrate, upland transition zone acreage dominated by native plants, and upland transition zone acreage with suitable wildlife refugia. When including indicators that integrated multiple taxonomic groups or ecosystem elements, there were multiple subregions that chose Ridgway's Rail, salt marsh harvest mouse, plant biomass, and invertebrate biomass.

Indicators of biotic integrity by ecosystem and subregion of SF Bay

A dot (●) indicates that the category of indicators was chosen for a subregion, and an X indicates a particular indicator was chosen within a category. Attribute of interest for all listed wildlife species was abundance unless otherwise noted.

Subtidal and intertidal mudflats

Indicator	North Bay	Suisun	Central Bay	South Bay
Physical			●	
Total mudflat acreage			X	
Subtidal water quality			X	
Plants	●	●		
Eelgrass acreage	X			
Acreage dominated by natives		X		
Birds	●			●
Ducks				
Divers				X
Shorebirds				
Diversity and abundance	X			
Winter abundance				X
Mammals				●
Harbor seal				X
Shellfish acreage	●			
Fish	●	●	●	
Salmonids	X			
Forage fish biomass			X	
Delta smelt		X		
Integrative	●		●	●
Acreage of native living substrate			X	X
Plant and invertebrate biomass	X		X	

Indicators of biotic integrity by ecosystem and subregion, continued.

Tidal marsh

Indicator	North Bay	Suisun	Central Bay	South Bay
Physical				●
1999 Bayland Goals criteria for marsh acreage, size, and connectivity are met				X
Plants	●			
Acreage dominated by natives	X			
Birds	●	●		●
Obligate tidal marsh species				
Diversity and abundance		X		
Ridgway's Rail	X			
Ducks				
Dabblers				X
Mammals	●	●		
Native small-bodied diversity and abundance		X		
Salt marsh harvest mouse	X			
Fish	●			
Diversity and abundance	X			
Integrative			●	●
Recovery criteria met			X	
Total plant and invertebrate biomass			X	
Ridgway's Rail & salt marsh harvest mouse				X

Indicators of biotic integrity by ecosystem and subregion, continued.

Managed wetlands

Indicator	North Bay	Suisun	Central Bay[a]	South Bay[b]
Birds	●	●		●
Breeding waterbird				X
Salt-pond specialists				X
Ducks				
Richness and density	X			
Winter abundance		X		
Divers				X
Shorebirds				▪
Diversity and abundance	X			
Small- to medium-size abundance				X
Snowy Plover				X
Mammals		●		
Salt marsh harvest mouse		X		
Fish	●			
Diversity and abundance	X[c]			

Upland transition zone

Indicator	North Bay	Suisun	Central Bay[a]	South Bay[b]
Plants	●	●		●
Eelgrass acreage				
Acreage dominated by natives	X	X		X[d]
Total biomass				
Acres with suitable wildlife refugia	X			X[d]
Birds	●			●
Ridgway's Rail				X
Song Sparrow and Common Yellowthroat	X			
Reptile and amphibian abundance	●			
Integrative			●	
Recovery criteria met			X	

[a] Central Bay ignored managed wetlands due to their small acreage in this subregion.

[b] Only managed ponds were considered for South Bay.

[c] Abundance of native fish for near-term, and density of native fish per wetland for long-term in North Bay.

[d] Acreage with suitable refugia for near-term, and acreage dominated by natives for long-term in South Bay upland transition zone.

Conservation action categories

Subregional teams of stakeholders were aware of many possible actions that could be taken to improve the biotic integrity of their subregion, and to make the decision tool tractable we developed six action categories that were adapted by each subregion:

1) *Protect acreage*: e.g. conservation easements, land acquisition
2) *Manage sediment* -- e.g. alter dam releases, beneficial reuse of dredge material
3) *Manage/protect species of special concern* -- e.g. predator management, translocation/captive breeding
4) *Manage vegetation community* -- e.g. plant natives, remove / treat against invasives
5) *Manage water quality and quantity* -- e.g. reduce contaminant inputs, regulate salinity, change water depth
6) *Manage human disturbance* -- e.g. manage recreation access, reroute transportation corridors

Two subregions included additional action categories that were unique to their subregion:

Restore acreage (South Bay only) -- expenditures on capital costs for infrastructure and staffing needed to conduct a restoration project, distinguishing this from other action categories representing annual expenditures on operations and maintenance of (multi-year) restoration projects.

Collect information (Suisun only) – expenditures on research, monitoring, and analysis to inform adaptive management within the near-term.

Future scenarios

An important step toward identifying recommended resource allocations was developing alternative future scenarios for resource availability (e.g., staff, funding, equipment) and external environmental drivers (e.g., extreme storms, sea level rise). Considering the full range of future uncertainty about these external drivers, we developed a rosy (aka optimistic) and a not-so-great (aka pessimistic) scenario.

External driver scenarios

Rosy	Not So Great
Near-term (2015-2029)	
Extreme storm events spaced out in time and not coinciding with big high tides	Multiple (2-3) extreme storms hitting at once & coinciding with king tides (like in 1986)
Expected levels of sea-level rise[a] (+40 cm from current) and sediment	Expected levels of sea-level rise (+40 cm from current) and sediment
Infrastructure (e.g., levees, dikes) maintained	Infrastructure (e.g., levees, dikes) fails
Temperature, salinity, DO, and pH regimes okay for native aquatic biota	High temperature impacts on native aquatic biota; Ocean acidification
Resources (e.g., staff, funding) at least double current levels	Resources (e.g., staff, funding) less than double current levels
Long-term (2030-2100)	
Extreme storm events spaced out in time and not coinciding with big high tides	Multiple (2-3) extreme storms hitting at once & coinciding with king tides (like in 1986)
Optimistic sea-level rise (+55 cm from current) and low sediment availability	Pessimistic sea-level rise (+165 cm from current) and low sediment availability
Infrastructure (e.g., levees, dikes) maintained	Infrastructure (e.g., levees, dikes) fails
Temperature, salinity, DO, and pH regimes okay for native aquatic biota	High temperature impacts on native aquatic biota; Ocean acidification
Resources (e.g., staff, funding) at least double current levels	Resources (e.g., staff, funding) less than double current levels

Sea-level rise scenarios in this table are based on Stralberg et al. (2011).

Resource allocation options

For each management time horizon, each subregion developed two resource allocation options: one that assumed a rosy future scenario for external drivers and another that assumed a pessimistic future for external drivers. Subregions differed in how they allocated resources among the Bayland ecosystems, which reflected the geographic variation in the constraints and opportunities for taking conservation action. When pooling allocations by ecosystem, the ecosystem-specific percentages did not differ substantially between allocation options for a given subregion. Most of the resources were allocated to tidal marsh and managed wetland, followed by migration space, subtidal and intertidal mudflats, and watershed. When comparing action categories, most resources were allocated toward protecting acreage and managing sediment.

Action categories receiving the most resource allocation by subregion in SF Bay

X = more allocated than expected by chance among the action categories; XX = more than double the amount expected by chance was allocated.

Subregion	Management horizon	Protect acreage	Manage sediment	Manage individual wildlife	Manage vegetation	Manage water	Manage human disturbance
North Bay	2015-2029	XX	X				
	2030-2050	X	X				X
Suisun[a,b]	2015-2029	X			X	X	
	2030-2050	XX				X	
Central Bay[a]	2015-2029	XX	X				
	2030-2050	X	X	X			
South Bay[c]	2015-2029		(X)		(X)	(X)	
	2030-2050	X	X		(X)	(X)	

[a] Longer-term (2030-2050) allocation options were not analyzed for Suisun or Central Bay.

[b] There was an additional category "collect information"for Suisun, but it did not receive a large percentage allocation and is not shown for simplicity.

[c] There was an additional action category in South Bay called "restore acreage", which represented principal resources directed toward the establishment of long-term restoration projects such as staff and equipment. The "manage ___" action categories, then, represented annual expenditures to maintain the long-term restoration projects. The (X) symbols represent the large amount allocated to this added category for both time horizons.

Bayland ecosystems receiving the most resource allocation by subregion within SF Bay

X = more allocated than expected by chance among the ecosystems.

Subregion	Management horizon	Subtidal & intertidal	Tidal marsh	Managed wetlands	Upland transition zone	Migration Space	Water-shed
North Bay	2015-2029			X	X	X	
	2030-2050			X	X	X	
Suisun[a,b]	2015-2029		(X)	X	(X)		
	2030-2050		(X)	X	(X)		
Central Bay[a,c]	2015-2029		X	na	X		
	2030-2050	X	X	na	X		
South Bay[d]	2015-2029		X	X	X		
	2030-2050		X	X	X	X	

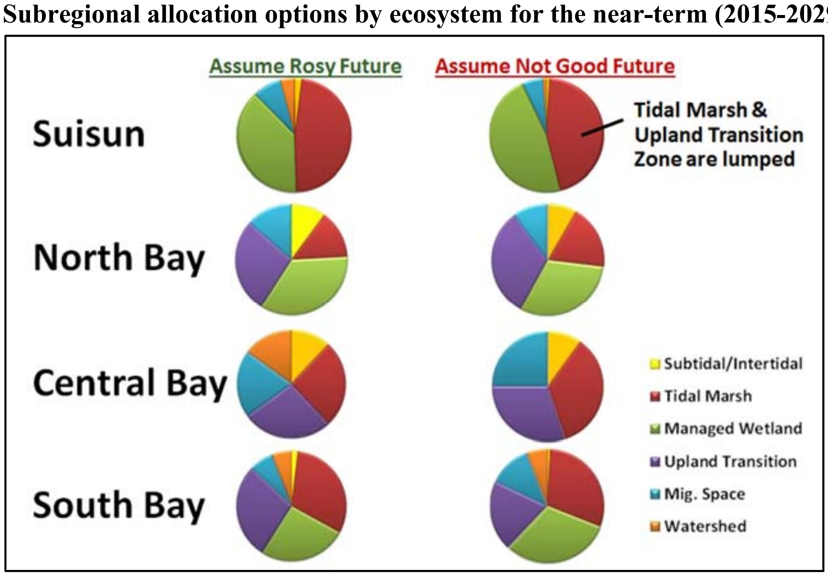
[a] Longer-term (2030-2050) allocation options were not analyzed for Suisun or Central Bay.

[b] The Suisun team considered tidal marsh and upland transition zone as a single ecosystem when assigning allocation percentages, and the (X) symbol represents the large amount allocated to this merged ecosystem in both management time horizons.

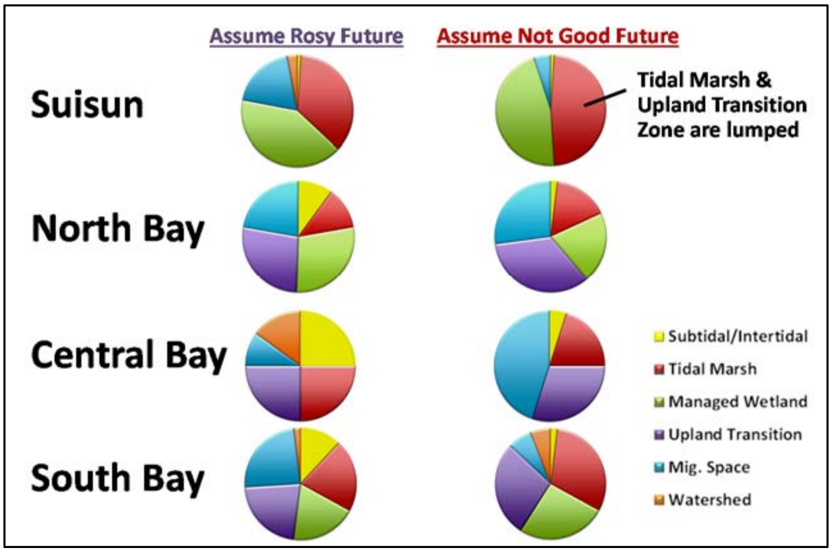
[c] Managed wetlands were ignored in Central Bay due to their scarcity in this subregion.

[d] Diked marshes were ignored within South Bay, and only managed ponds were considered within the managed wetlands ecosystem classification.

Subregional allocation options by ecosystem for the near-term (2015-2029).



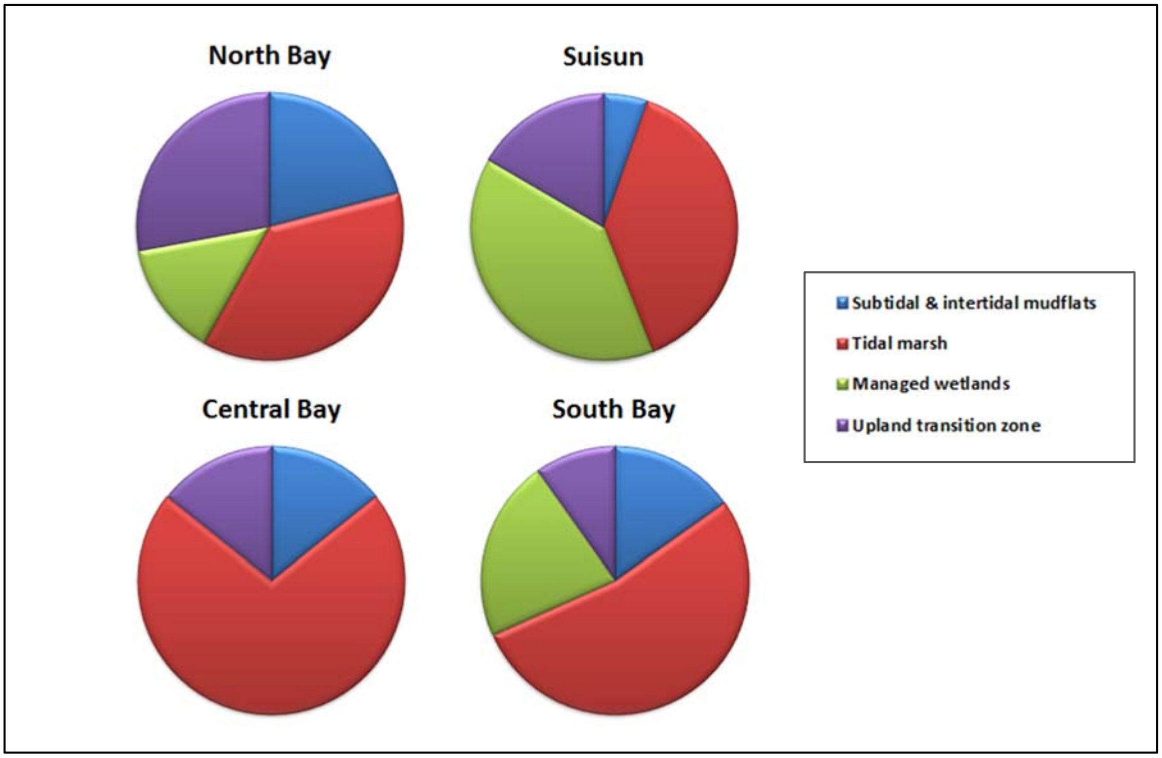
Subregional allocation options by ecosystem for the longer-term (2030-2050).



Tradeoffs between ecosystems and outcome horizons

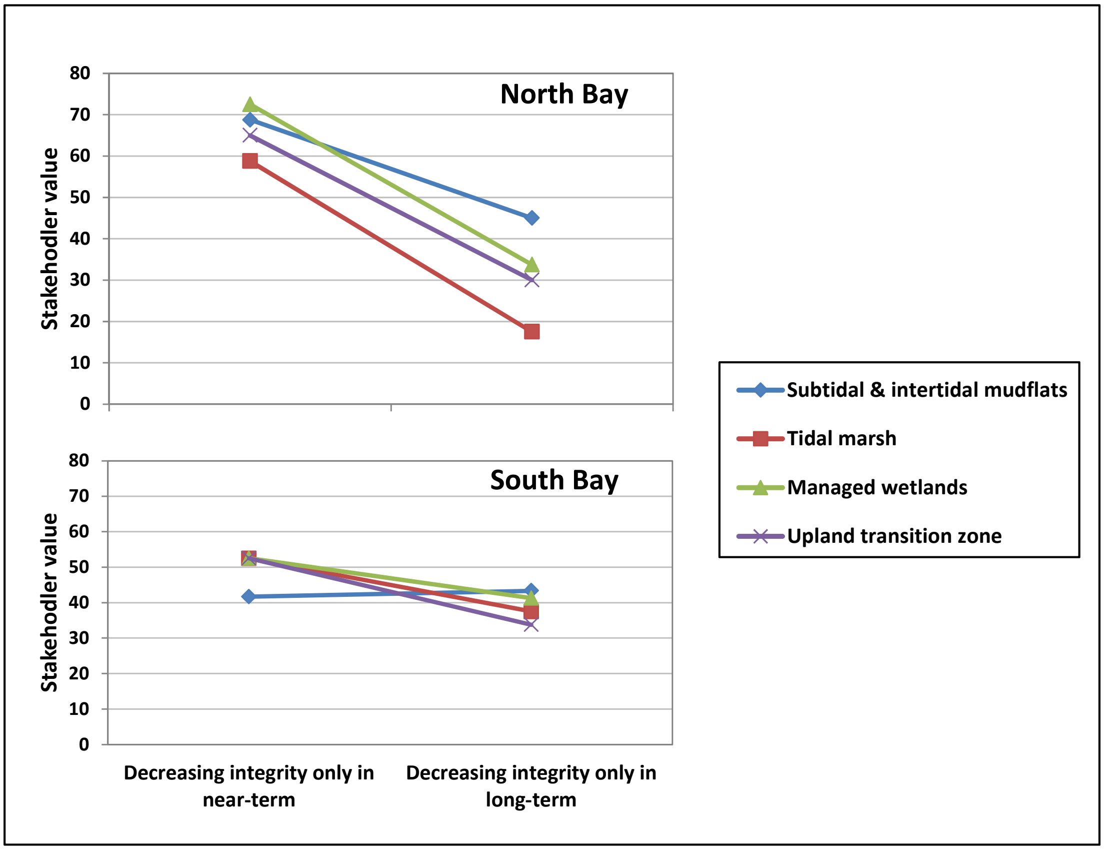
For each combination of possible outcomes for ecosystem-specific conservation objectives, stakeholders independently assigned a value on a scale from 0-100 with 0 representing the worst possible combination and 100 representing the best possible combination of outcomes. Based on these inputs, we found that tidal marsh had relatively high importance in all subregions.

Relative importance of estuarine ecosystems by subregion in the near-term (2015-2029)



North Bay and South Bay stakeholders completed the long-term portion of their decision tools. Stakeholders in each of these subregions, as was done for tradeoffs between ecosystems, independently assigned values to possible combinations of outcomes for changes in biotic integrity for the near-term (2015-2029) and long-term (2030-2100) outcome horizons. For both of these subregions, stakeholders on average were more averse to decreasing biotic integrity in the long-term than they were in the near-term for each of the estuarine ecosystems, and this contrast was most evident in North Bay. The one exception was for South Bay, where stakeholders had a similar aversion to decreasing biotic integrity for subtidal and intertidal mudflats in the near-term as they did in the long-term.

Tradeoffs between outcome horizons by ecosystem in North Bay and South Bay



Recommended allocations and main findings

As we did with the stakeholder values, each stakeholder independently provided a predicted probability for the external driver scenarios and for how these external drivers in combination with the allocation options (and in some cases intermediate drivers) affect indicators of biotic integrity. They also provided probabilities that biotic integrity as a whole would be stable or increasing based on changes in the chosen indicators. Based on a quantitative, decision-analytic approach that integrates the stakeholder values and probabilities we found that the recommendation for all subregions was to allocate resources in a way that assumes a rosy future for external environmental conditions (including climate and extreme storms) and for availability of resources.

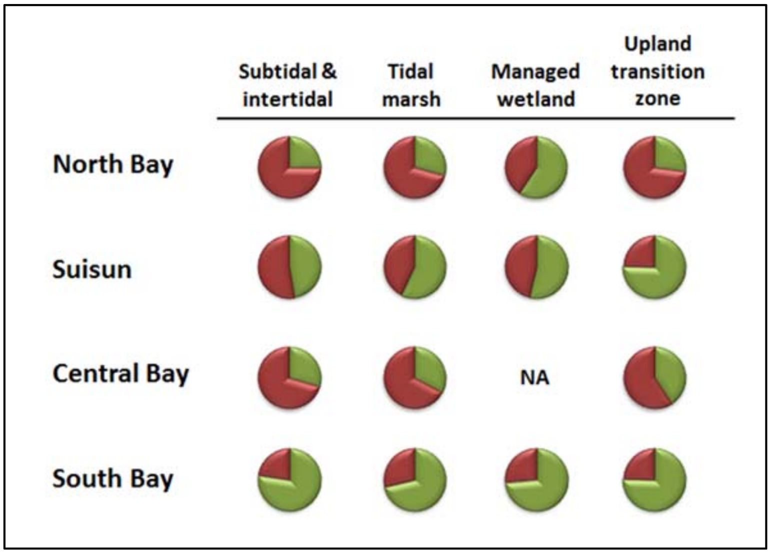
This recommendation was surprising to some stakeholders, who would have thought that a more conservative approach should be taken to conservation in the Baylands. Intuitively, we should try to do everything we can to prepare for the worst possible scenarios for external drivers including climate change and availability of sediment and resources (funding, staff, equipment). This intuitive reasoning was not supported by the results from CADS, however. Instead, stakeholders were on average more optimistic about the effectiveness of an allocation option that assumes a rosy future even if the future turns out to be not so great for the external drivers. In other words, stakeholders believed the assume-rosy allocation to be robust to worse-case scenarios for the external drivers.

South Bay had the most optimistic predictions for biotic integrity across ecosystems, and Suisun also had greater than 50% chance of stable or increasing biotic integrity in every estuarine ecosystem except subtidal and intertidal mudflats. Except for managed wetlands, North Bay and Central Bay predicted a less than 50% chance that biotic integrity would be increasing in each ecosystem. Across the board, there was substantial uncertainty about the projected trajectory of biotic integrity; the ecosystem-by-subregion probabilities of stable or increasing biotic integrity were all between 20 and 80%. Expected performance[1] ranged from 47-58% among subregions when implementing the assume-rosy-future allocation and 39-55% when implementing the assume-not-so-great-future allocation.

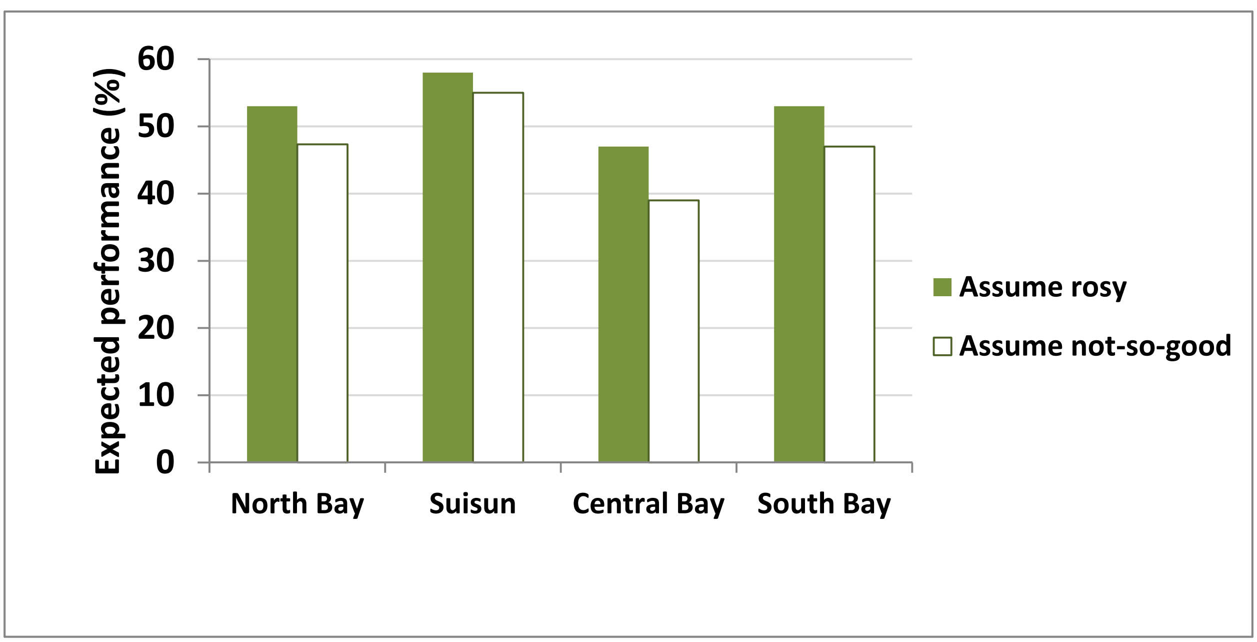
[1] Expected performance was measured in terms of the values stakeholders placed toward tradeoffs among ecosystems and, in the case of North Bay and South Bay, between the near-term and long-term outcomes. Tradeoffs were quantified in terms of possible changes in biotic integrity in the focal estuary ecosystems (see section 3.6).

Predicted changes in biotic integrity by ecosystem and subregion

The green portion of each circle represents the probability of stable or increasing biotic integrity for the respective estuarine ecosystem for each subregion in the near-term (2015-2029). Central Bay did not consider managed wetlands, and South Bay only considered managed ponds within the managed wetlands class.



Expected performance (% chance of stable or increasing biotic integrity across ecosystems) of assume-rosy resource allocation by subregion



Lessons learned

For the first time, stakeholders engaged in resource management of SF Bay have collaboratively arrived at a set of conservation objectives that were explicitly used to inform optimal allocation of resources among ecosystems and action categories for each of the four subregions. These resource allocation recommendations build upon many years of conservation planning and habitat delivery in the region, which have provided essential ingredients including conservation objectives, management options at from segment to regional scales, monitoring and scientific information, and predictive models about the effects of management actions and external environmental drivers on estuarine ecosystems. The added value of CADS Phase 1 has been to bring all these ingredients together in a transparent, collaborative decision-analytic framework to develop recommendations for allocating limited conservation resources at subregional scale.

The project design was structured such that CADS Phase 1 would be compatible with the Bayland Ecosystems and Habitat Goals Update (BEHGU), a technical update to the original Baylands Habitat Goals, which was being developed concurrently by a broad coalition of Bay Area scientists to develop management recommendations that account for projected climate change. This required much communication and coordination within the CADS leadership team itself along with communication and coordination between the leadership team and stakeholders, especially the BEHGU coordinators. The importance of strong leadership, project management and coordination, and stakeholder engagement cannot be overstated for a project with this level of complexity.

A particular strength of CADS was engaging a broad suite of stakeholders throughout the process of developing conservation objectives, indicators of biotic integrity, action categories, allocation options, and recommendations. It is these individuals who can interpret and implement the recommended allocations in the subregions and ecosystems where they work. CADS Phase 1 was carried out on a very modest budget considering the broad scope, depth and complexity of the problem that was addressed, which has demonstrated that such an ambitious project can be accomplished without a large financial investment. The project brought together a representative set of stakeholders and made them more cognizant that resource allocations should account for future uncertainties and that the allocations differ among subregions.

Chapter 1. <u>Motivation for project</u>

Resource managers in the Baylands of San Francisco Bay have continually struggled with prioritizing resource management decisions in a dynamic environment, from the subtidal zone through the tributary watersheds that feed into the San Francisco Bay Estuary. The Baylands are managed by a diverse set of landowners and has caught the interest of many stakeholders including conservation groups, birdwatchers, hunters, and tourists. Adding to this complexity is oncoming sea-level rise, increasing intensity and frequency of extreme weather events including storms and droughts, compounded by intense human development around the Baylands. Recent research has shown projected losses of tidal marsh and upland transition zone within the Estuary due to sea-level rise (Stralberg et al. 2011; Appendix A). Although these threats are affecting the entire Estuary, managers are focused on the footprint of their local projects and managing them with limited resources. Because most restoration projects are not planned and executed on a landscape scale, managers have struggled with determining ways to measure impacts of their conservation actions beyond their specific project site. This has brought about a great need for consistently agreed-upon conservation objectives (beyond listed species recovery objectives) in the Estuary against which to make management decisions and measure conservation effectiveness. In an era of uncertain future funding, resource management, and monitoring resources, coupled by the identified environmental threats, resource managers are asking for expertly-vetted recommendations for allocating limited resources toward accomplishing the identified conservation objectives in the Estuary.

A workshop sponsored by the California Landscape Conservation Cooperative was held in October 2011, during which stakeholders and scientists identified a recommended resource allocation to conserve tidal marshes of San Francisco (SF) Bay from 2012 through 2050 (Thorne et al. 2015). The recommendation was based on a structured-decision-making process and decision-analytic tool that took into account uncertainties including extreme storm events and response of the tidal marsh ecosystem to management action alternatives (aka resource allocation) and to external drivers. A take-home message from the 2011 workshop was that increased investment in climate adaptation actions would be smarter than the status quo strategy that takes minimal consideration of future climate-change impacts. Climate adaptation actions would include engineering options to improve resilience of tidal marsh to sea-level rise and storms, improving the health of existing tidal marshes, and biophysical modeling of tidal marsh response to climate change to inform these climate adaptation efforts. Actions that would allow marshes to move with sea-level rise would include identifying and prioritizing areas where tidal marshes could migrate, acquiring open lands adjacent to existing tidal marsh, and removing infrastructure barriers to marsh transgression.

The motivation for the 2011 workshop was the great level of uncertainty about climate change impacts on tidal marsh resources and how these could be addressed, if at all, by altering existing restoration and management strategies across conservation-oriented partners working in SF Bay. Individual land managers and coordinators within the Bay have to grapple with uncertainty related to climate change and would benefit from a transparent and objective process leading to management priorities that optimize use of limited budgets for conservation in the face of sea level rise and other projected climate change impacts.

Since 2012, the Bayland Ecosystem Habitat Goals Update (BEHGU) has been developing a list of recommended goals and actions at multiple spatial scales that address projected climate change impacts for conservation within each ecosystem of the Baylands that include SF Bay. In particular, BEHGU focuses on three spatial scales: 1) region – throughout the Baylands; 2) subregions – North Bay, Suisun, Central Bay, and South Bay; and 3) segments – each subregion is broken into multiple planning units that each span multiple ongoing conservation projects. BEHGU recommendations are meant to accommodate future climate scenarios, but there is no underlying decision process or tool to justify the ultimate selection of recommendations (from a set of candidate recommendations) nor are the recommendations specified for particular time periods or resource availability scenarios. This called for an evaluation of how alternative ways of allocating resources among BEHGU-recommended actions would be expected to perform, so that more actionable and defensible recommendations could be identified that explicitly account for uncertainties regarding management outcomes and effects of external drivers that are beyond the control of management (e.g., climate change, resource availability).

Recommendations from the 2011 workshop combined with knowledge gaps revealed through BEHGU led to six main challenges:

7) Engage a broader suite of stakeholders and experts engaged in conservation of SF Bay.
8) Account for subregional differences with regard to the costs and constraints of taking climate-adaptation actions, suites of conservation objectives, and uncertainties regarding management effectiveness, sediment dynamics, and climate-change impacts.
9) Address the linked nature of decisions, objectives and outcomes across time and space. Decisions about project-level actions taken in the near future should account for the consequences of actions taken in the more distant future. Likewise, decisions should account for project-level actions scaling up to influence the subregional and regional-level objectives.
10) Incorporate additional system components, including habitat types (e.g. tidal flats, low marsh, mid-marsh, high-marsh, upland transition, managed ponds) and species of conservation concern with contrasting requirements compared to Ridgway's Rail (e.g., salt marsh harvest mouse, shorebirds). Consider especially tradeoffs with respect to contrasting responses of multiple species/communities and associated transitions of spatial elements from one estuarine environment type to another.
11) Consider a broader response horizon going out to 2100 to bring in the full range of uncertainty about future sea-level rise.
12) Inform design of an adaptive management and monitoring program that guides and evaluates the climate adaptation strategy by addressing key sources of uncertainty with high value of information.

In response to these six challenges the CADS (Climate Adaptation Decision Support for SF Bay) project was undertaken by the San Francisco Bay Joint Venture, a collaborative partnership for the protection, restoration, and enhancement of all types of wetlands for the benefit of birds, other wildlife, and people. CADS was an answer to a call from managers to measure the impacts of conservation actions on a landscape level while helping ensure that current conservation and management actions optimize the potential to address climate change in an era of limited resources.

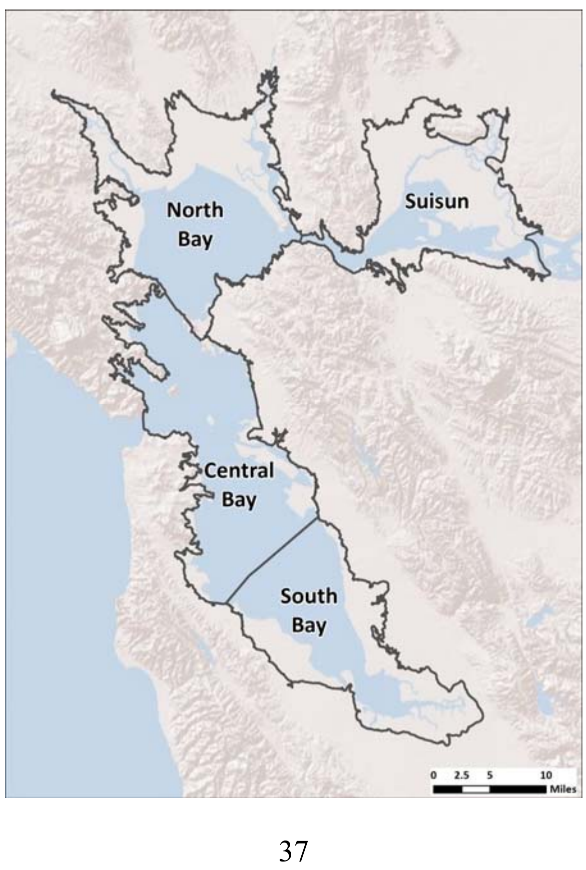
The project is divided into two phases, with Phase 1 focused on establishing regional and subregional conservation objectives leading to recommended resource allocations for each of the four subregions in SF Bay (North Bay, Suisun, Central Bay, and South Bay; Figure- 1.1). Phase 2 will demonstrate how subregional recommendations can inform local-scale climate adaptation strategies. In particular, climate adaption recommendations for the North Bay subregion (from Phase 1) will be used to inform development of the San Pablo Bay NWR climate adaptation plan (in Phase 2). This report describes the set-up and findings from CADS Phase 1 (henceforth, CADS).

To address the challenges above, we identified three primary goals for CADS Phase 1:

1) Arrive at recommended resource allocations that cut across jurisdictional boundaries to conserve estuarine ecosystems within each subregion of SF Bay
2) Provide basis for discussion when consulting with partners on their individual projects as part of the San Francisco Bay Joint Venture (SFBJV) Design Review Program
3) Identify suite of measurable conservation objectives from regional (San Francisco Bay Estuary) to subregional scales (North Bay, Suisun, Central bay, South Bay) that can be communicated in the upcoming revision to the SFBJV Implementation Strategy and used as a means of assessing conservation success at regional and subregional scales and thereby support an adaptive management framework.that is linked to a coordinated monitoring effort.

Figure- 1.1. Map of subregions in Baylands of San Francisco Bay.

Map credit: Brian Fulfrost.



Chapter 2. Project orientation and stakeholder engagement

2.1 Overview

The CADS project provides decision tools and recommendations for natural resource and decision-making by natural resource managers in each of four subregions within the San Francisco (SF) Bay Estuary and surrounding Baylands: North Bay, Suisun, Central Bay, and South Bay (Figure- 1.1). The recommendations account for the unique decision contexts in each subregion regarding conservation objectives, threats, and constraints to management actions. The recommendations are based on a decision-analytic approach that accounts for uncertainties including climate change and effects of management on desired and measurable outcomes for conservation. The framework informs resource management decisions within near-term (2015 - 2029) and longer-term (2030-2100) management horizons to maintain or increase indicators of biotic integrity in four ecosystems within the SF Bay Estuary during the near-term and long-term (2030-2100). This project provides management recommendations for allocating resources among categories of actions within six Bayland ecosystems to conserve biotic integrity within four estuarine ecosystems in the SF Bay.

A key end product from CADS Phase 1 was to provide conservation decision-makers with subregional-scale recommendations that could be used for actual on-ground conservation actions in the SF Bay. Intermediate products for arriving at the recommendations include: 1) conservation objectives (what stakeholders want to ultimately achieve and associated metrics), 2) action categories, 3) scenarios for external drivers beyond the control of management (e.g., resource availability and climatic factors), 4) resource allocation options by subregion and Bayland ecosystem, and 4) diagrams documenting linkages between external environmental drivers, management actions and conservation objectives. Rather than being purely prescriptive the recommendations and the intermediate products are intended to be used in concert with other decision-support tools, planning documents, and other relevant literature (e.g., Goals Project 1999, Stralberg et al. 2011, Veloz et al 2013). Products from CADS Phase 1 can then be fed into local-scale climate adaptation efforts, which will be demonstrated during Phase 2 by focusing on San Pablo Bay National Wildlife Refuge as a case study. A longer-term vision is that the products from Phase 1 form the basis of a formal adaptive management framework that tightly links conservation outcomes (via monitoring) with ongoing management decisions in the SF Bay.

CADS Phase 1 began with a series of steps (Table 2.1.1) that were aimed at developing Bayland-wide products that could be used as starting points for refinement and customization for each subregion. For example, a set of conservation objectives and candidate measurable attributes were identified for each estuarine ecosystem that were later modified to suit the interests of stakeholders working in a particular subregion. By starting with Bayland-wide products, this allowed for greater consistency in the subregional approaches and products. Project steps were carried out through a series of orientation webinars, a stakeholder workshop, and follow-up webinars with stakeholders to finish the products and arrive at final subregional recommendations. See Appendix B for a complete project timeline.

The steps are based on a collaborative decision analytic approach (CDA) and structured decision making (SDM), which were applied in developing a decision framework to inform tidal marsh conservation in SF Bay via the 2011 workshop (Thorne et al. 2015). CDA and SDM involve terminology that is likely unfamiliar to many stakeholders working in SF Bay, and we have made an effort to adapt the terminology so that it is more understandable for the conservation community. The glossary at the end of the report provides definitions for these specialized terms, and those most frequently used are defined in

Table 2.1.2.

A primary goal of this project was to engage a broader suite of San Francisco Bay partners in developing a spatially-explicit climate adaptation framework for subregions of the San Francisco Bay. Section 2.2 describes how that part of this original goal was achieved, whereas the remaining subsections below focus on how the climate adaptation framework was developed.

We used an iterative approach within and between steps of the project (Table 2.1.1), which involved many discussions with stakeholders (see section 2.2 below) during webinars, a 2-1/2 day workshop, individual meetings, and e-mails. Products generated during each step were also informed by existing conservation planning documents and decision-support tools for SF Bay. This open approach helped ensure that stakeholder input and existing information formed a basis in developing the ingredients needed (Steps 1-6) to make final management recommendations (Step 7) and that they could use the products that emerged. The focus of this project was on the products being usable by stakeholders rather than on following a predetermined series of steps.

Table 2.1.1. Steps for developing Bayland wide products.

Step num.	Step name	Questions addressed	Section of report
1	Engaging stakeholders and experts	Who are the individuals and groups having influence or being influenced by the decisions?	2.2
2	Framing subregional decisions	What type of decision must be made (e.g. resource allocation)? Who are the stakeholders? What are the spatial and temporal scales?	3.1
3	Identifying and defining conservation objectives	What are the ultimate desired outcomes for the stakeholders?	3.2
4	Identifying & refining action categories	What actions can be taken to reach the conservation objectives?	3.3
5	Developing future scenarios and resource allocation options	What are two scenarios for future resource availability and external environmental drivers? How would resources be best allocated under each scenario for the future?	3.4
6	Making predictions	How are conservation objectives linked with action categories and external drivers in an influence diagram? What are measurable attributes for the linked factors? What is the likelihood that an allocation option (Step 5) will achieve each conservation objective (Step 3) given scenarios for resource availability and external drivers?	3.5
7	Identifying & quantifying trade-offs	How do stakeholders value possible outcomes for competing conservation objectives?	3.6
8	Identifying recommended resource allocations	Which allocation option (Step 5) has the greatest expected conservation benefit, accounting for the uncertainties?	3.7
9	Comparison of subregional decision tools and recommendations	What are key similarities and differences among subregions and how might this inform future cross-subregional conservation efforts?	Chapter 6

Table 2.1.2. Definitions of frequently used technical terms in this report.

Definitions of terms used to describe the steps of collaborative decision analysis (Thorne et al. 2015), which have been adapted from the structured decision-making process. These terms are also defined in the glossary.

Action category -- a set of conservation actions that are related in some way, e.g. a manage-water category could include management actions that affect water levels and water quality. An action category allows for reduced complexity when developing alternative management options.

Allocation options / allocate -- proportional expenditures among alternative conservation actions or action categories. An allocation may be specified for implementation at a single point in time or space, or for a series of implementations over time and across space.

Conservation objective -- ultimate desired outcome (formal SDM term: fundamental objective) to be achieved by decision makers and other stakeholders through conservation actions that could be taken. Can be an overarching phenomenon that cannot be directly measured (e.g., biotic integrity) but must be associated with one or more measurable attributes.

Decision frame / framing -- description of decision to be made, including the type of decision to be made (e.g. resource allocation or discrete choices), regulatory context, relevant decision-makers and stakeholders, and spatial and temporal scales.

External driver -- factor that affects conservation objectives but is beyond the control or influence of the relevant decision makers. Examples include climatic conditions, resource availability, and decisions or policies enacted by upper government levels.

Factor -- refers to any element within an influence diagram or decision tool, including conservation objectives, intermediate drivers, external drivers, and actions or action categories.

Influence diagram -- diagram linking actions or action categories and external drivers to fundamental objectives, often via intermediate outcomes.

Measurable attribute / metric -- quantitative units (e.g., population size) for an indicator of biotic integrity or for a driver (e.g., sediment supply), which enables predictions to be made.

Resources / resource availability - time, money, and staff available to implement conservation actions.

Scenario -- a possible future set of conditions regarding resource allocations, external drivers, intermediate drivers, and/or indicators of biotic integrity.

Stakeholder -- an individual or entity that has direct influence or is influenced by a particular decision or set of decisions.

Trade-offs – quantified levels of satisfaction or happiness that one or more stakeholders assign to scenarios for multiple conservation objectives

2.2 Engaging stakeholders and experts

An essential component to this project was engaging the relevant stakeholders to ensure that the recommendations and products from this project would be defensible and useable by on-ground decision-makers. We define a stakeholder as an entity who has direct influence or is influenced by a particular decision or set of decisions for conservation in SF Bay. By framing the decision early in the project (see section 3.1 and timeline in Appendix B), we were able to better identify the appropriate set of stakeholders to include as participants. We began by identifying a core team (Table 2.2.1) consisting of partners involved in the 2011 workshop (Thorne et al. 2015) along with individuals having leadership roles with the Bayland Ecosystems and Habitat Goals Update (BEHGU) (California State Coastal Conservancy 2014). These stakeholders were essential to ensure that the products of CADS would complement BEHGU and address the challenges that emerged after the 2011 workshop. The leadership team was primarily responsible for carrying out CADS Phase 1 and was an expanded set of individuals who coauthored the funded project.

We initially engaged this core team of stakeholders via a webinar, where we described the goals of the project and plans for a workshop with a broader group of stakeholders. The core team provided initial feedback on the project aims and in particular an initial description of the decisions to be addressed as part of CADS Phase 1 (see section 3.1) and on the specific approaches to be applied during the stakeholder workshop in May 2014. Additionally, some members of the core team served as coordinators of break-out groups during the stakeholder workshop.

We invited 49 stakeholder groups, of which 27 (over half) had a representative participating in at least one CADS sponsored event (Table 2.2.2). Except for the decision analysts, project advisors and facilitator, all participants in the project were classified as stakeholders even if the primary function of their organization was providing information or decision-support tools for managers in the SF Bay (e.g., Point Blue, San Francisco Bay Bird Observatory) rather than on-ground conservation actions (e.g., U.S. Fish & Wildlife Service refuges, California Department of Fish & Wildlife). Stakeholders who participated also provided the expertise needed to generate defensible recommendations for conservation in the Baylands. Organizations whose primary role was funding conservation (e.g., California State Coastal Conservancy) or regulating conservation actions (e.g. USFWS Ecological Services) in the Baylands were also key stakeholders.

Although we recognized the importance of entities that are affected by conservation decisions in the Baylands but are otherwise not taking an active role in them (e.g., Google), we decided not to engage them directly. Actively engaging these entities in the project would have required extensive outreach to not only convince them to participate but also to bring them up to speed on all the issues surrounding conservation in the Baylands. Furthermore, engaging this additional set of stakeholders would have stretched beyond our capacity to maintain their involvement and interest throughout the project. Instead we engaged a representative of the San Francisco Estuary Partnership, which is an organization working with businesses, local municipalities, government agencies, and nonprofit organizations in implementing conservation projects in the Baylands.

Stakeholders provided critical input during orientation webinars, the stakeholder workshop, and after the workshop. Originally, we had planned on stakeholder participation consisting of preparation and participation in the orientation webinars and in the stakeholder workshop. Because stakeholders felt there was not enough time allotted during the webinars and workshop to adequately develop recommendations, stakeholder involvement extended beyond the workshop finalize the subregional recommendations and associated products. Stakeholder involvement declined after the workshop, but the subregional groups were maintained by 3-7 stakeholders working with a decision analyst to complete the respective decision tools via webinars and emails. Garnering initial engagement of stakeholders and maintaining this engagement was crucial to the completion of the project.

Our main vehicles for engaging stakeholders were emails, webinars, workshop, CADS website[2], Google drive, and occasional individual phone calls and meetings. We emailed stakeholders invitations and reminders to attend webinars and the workshop, and emails often referred to the CADS website with links to agendas and documents explaining the decision frame, conservation objectives, action categories, and hypothetical conservation recommendations stored on Google drive. We also posted on the website the presentations, recordings of the conversation, written stakeholder comments along with team leader responses to comments regarding the core-team and stakeholder orientation webinars. We found it was important to maintain transparency by documenting conversations and providing feedback to questions that arose. For the workshop participants, we provided an information packet (hardcopy) that included a summary of the decision framework that had been refined through the orientation webinar series (Appendix C).

[2] https://sites.google.com/site/sfbaystructureddecisionmaking/home

Table 2.2.1. Core and leadership teams.

Roles and affiliations of core and leadership teams involved with Phase 1 of CADS. Asterices (*) indicate the members who helped identify a recommended allocation for conserving tidal marsh in SF Bay as part of a structured-decision-making workshop in 2011 (Thorne et al. 2015). Plus (+) indicates author of funded CADS proposal.

Roles	Affiliations
Leadership team members	
Project coordinators (2)*+	San Francisco Bay Joint Venture
Project advisor*+	USFWS-Inventory and Monitoring Program
Collaborative decision analyst*+	Independent contractor
Collaborative decision analyst	Cornell University
Collaborative decision analyst*	University of Vermont
Professional facilitator	Independent contractor
Core team of stakeholders	
BEHGU Coordinator	CA State Coastal Conservancy
SF Bay Program manager*	CA State Coastal Conservancy
Ecologists (2)	Point Blue Conservation Science
Ecologist*	USGS Western Ecological Research Center
Biologist*	USGS South Bay Salt Pond Restoration Project
Biologist*	USFWS Endangered Species Branch

Table 2.2.2. Stakeholders who participated in CADS Phase 1.

Affiliation	Program and/or Position
Brian Fulfrost and Associates	Founding Principal
California Dept. Fish & Wildlife	Napa-Sonoma Marsh Wildlife Biologist
California Landscape Conservation Cooperative	Science Coordinator
California State Coastal Conservancy	Bayland Ecosystems and Habitat Goals Update Author
California State Coastal Conservancy	South Bay Salt Pond Restoration Project Coordinator
California State Coastal Conservancy	Subtidal Habitat Goals Author
California State Parks	Program Manager
Central Valley Joint Venture	Science Coordinator
Ducks Unlimited	San Francisco Bay Regional Biologist
GAIA Consulting	Principal
Marin Audubon Society	President
Marin County Public Works	Flood Control Division Senior Engineer
National Oceanic and Atmospheric Administration	West Coast Coastal Manager
Point Blue Conservation Science	Quantitative Ecologists
Richardson Bay Audubon Center & Sanctuary	Director
San Francisco Bay Bird Observatory	Director
San Francisco Bay Bird Observatory	Habitats Program Senior Ecologist
San Francisco Bay Joint Venture	Coordinators
San Francisco Bay National Estuarine Research Reserve	Interim Director
San Francisco Bay Regional Water Quality Board	Executive Officer
San Francisco Estuary Invasive Spartina Project	Project Director
San Francisco Estuary Partnership and Association of Bay Area Governments	Director
Save the Bay	Habitat Restoration Director
Sonoma Land Trust	Conservation Director
Suisun Resource Conservation District	Executive Director
US Fish and Wildlife Service	
San Francisco Bay National Wildlife Refuge Complex	Manager and Biologist
Coastal Program	San Francisco Bay Manager
San Pablo Bay National Widllife Refuge	Biologist
Ecological Services	Sacramento Fish & Wildlife Office Lead Biologist
US Geological Survey - Western Ecological Research Center	South Bay Salt Pond Restoration Program Lead Scientist

Table 2.2.3. Subregional teams.

An asterisk (*) denotes the coordinator during workshop breakouts. Suisun was coordinated by a leadership team member. A stakeholder with Marin Audubon Society (+) participated on the North Bay and Central Bay teams.

Affiliation	Program and/or position	Workshop	Post-workshop
North Bay			
California Dept. Fish & Wildlife	Napa-Sonoma Marsh Wildlife Biologist		X
GAIA Consulting	Principal		X
Marin Audubon Society+	President	X	X
Point Blue Conservation Science	Quantitative Ecologists	X	
USFWS Endangered Species Branch*	Sacramento Fish & Wildlife Office Lead Biologist	X	
USFWS San Pablo Bay National Widllife Refuge	Biologist	X	X
USFWS-SF Bay National Wildlife Refuge Complex	Manager	X	X
Suisun Bay			
Suisun Resource Conservation District	Executive Director	X	X
CA State Coastal Conservancy	Bayland Ecosystems and Habitat Goals Update Coordinator	X	
Independent	Consulting Environemntal Scientist	X	X
Central Valley Joint Venture	Science Coordinator	X	X
Central Bay			
Save the Bay	Habitat Restoration Director	X	
Point Blue Conservation Science	Quantitative Ecologist	X	X
State Parks	Program Manager	X	X
CA State Coastal Conservancy*	Bayland Ecosystems & Habitat Goals Update Author	X	
CA State Coastal Conservancy	Subtidal Habitat Goals Author	X	
Richardson Bay Audubon Center & Sanctuary	Director	X	X
San Francisco Bay Joint Venture	Coordinator		X
Marin Audubon Society+	President		X
South Bay			
State Coastal Conservancy	South Bay Salt Pond Restoration Project Coordinator	X	
San Francisco Bay Bird Observatory	Director	X	X
USFWS Coastal Program	SF Bay Manager	X	
SF Estuary Invasive Spartina Project	Project Director	X	X
Ducks Unlimited	SF Bay Regional Biologist	X	
SF Bay National Wildlife Refuge Complex	Biologist	X	X
US Geol. Survey - Western Ecol. Research Center*	South Bay Salt Pond Restoration Program Lead Scientist	X	X

Chapter 3. Bayland wide products for subregional decision tools

This chapter describes the Bayland wide products needed for developing the subregional decision tools (see Chapter 5). In Chapter 4, further details are provided on how the products were developed with particular emphasis on stakeholder involvement. The current chapter then is a briefer summary of how the steps (Table 2.1.1) were carried out, with a focus on the end products from each step.

3.1 Framing subregional decisions

Defining the decisions to be made within each subregion was an essential part of the project to ensure that the right questions were being asked so that the products would be defensible and usable by the relevant stakeholders. In the context of the problem at hand (see Chapter 1), we framed the decision by defining the type of decision to be made, the relevant stakeholders (including resource managers and conservation planners), at which spatial and temporal scales the decision would be implemented, and over which spatial and temporal scales the outcomes would be predicted. Through discussions with stakeholders (see section 4.1), the decision frame was developed and refined in an iterative fashion (Table 3.1.1, Table 4.1.4, Figure 3.1.1), culminating in a concise question that summarizes the decision frame:

How should limited resources be allocated across time and space toward potential actions within subregions to conserve San Francisco Bay estuarine ecosystems while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?

A particularly important product from the decision framing discussions was a classification of Bayland ecosystems (Table 3.1.2), which was used for developing resource allocation options and defining conservation objectives as later steps in the process.

The goal of this section is to summarize the iterative evolution toward a final decision frame, from project inception through the end of the stakeholder workshop (for project timeline see Appendix B). A major challenge for framing the decision was trying to meet the diverse needs and desires of participating stakeholders (see section 2.2). We made a strong effort to accommodate stakeholder input, as these are the would-be users of the CADS recommendations. Section 4.1 provides a more detailed account of how stakeholder input was incorporated into the decision frame.

Table 3.1.1. Evolution to a final description of decisions (decision frame).

Descriptions of conservation decisions within subregions of SF Bay to be addressed in CADS Phase 1. The **top level** of the outline represents the final descriptions, and the **lower levels** describe their evolution. See section 4.1 for more details.

1) *Spatial extent of conservation objectives*: Estuarine ecosystems in each subregion of SF Bay (Figure- 1.1).
   - During the core team webinar it was suggested that we focus on a subset of estuarine ecosystems for which there was sufficient information and tools for making justifiable management recommendations. Thus, we proposed excluding subtidal and intertidal mudflat ecosystems.
   - During the orientation webinars the consensus was to include rather than exclude subtidal and intertidal mudflat ecosystems, as they are inextricably linked to other estuarine ecosystems and are part of BEHGU[a]. Some resource managers stressed the importance of including all of the estuarine ecosystems, because they are all linked and their integrity must be traded off when they are making management decisions.
2) *Type of decision to be made, spatial scales, and timing*: Allocation of management resources (e.g., time and funding) among action categories in one of six Bayland ecosystems within each of four subregions during near-term (2015-2029) and longer-term (2030-2050) management horizon.
   - Until midway through the orientation webinar series, we had considered developing allocation options at the level of individual segments within each subregion. It was determined that it would be infeasible (at this time) to develop allocation options for each of the 20 segments in SF Bay.
   - Until the orientation webinar series we considered having a single management horizon 2015-2050. Having two management horizons allows for setting up a formal adaptive management program[b].
3) *Outcome horizons*: Outcomes of allocation options and external drivers projected over a near-term (2015-2029) and long-term (2030-2100) horizon.
   - The decision framework from the 2011 workshop[c] projected outcomes out to 2050, beyond which uncertainty about sea-level rise increases exponentially. A strong recommendation after that workshop was to revisit the allocations considering a longer outcome horizon out to 2100.
   - Until the orientation webinar series we considered having just a single outcome horizon 2015-2100. Having two outcome horizons allows for setting up a formal adaptive management program[b].

[a] Bayland Ecosystems and Habitat Goals Update, which will recommend actions that account for future climate change.
[b] Resource allocations during the longer-term management horizon could be selected based on changes in ecosystem conditions during that timeframe (via monitoring) and updated scientific information about predicted effects of allocation options and external drivers on the long-term (2030-2100) conservation objectives.
[c] A workshop was held in 2011 with stakeholder and scientists to identify a recommended resource allocation to conserve tidal marshes throughout SF Bay (Thorne et al. 2015).

Figure 3.1.1. Final conceptual model describing decisions.

Final conceptual model representing decisions to be addressed in CADS Phase 1. Alternatives represent the subregion-specific allocation options for each management horizon, fundamental objectives represent the ultimate desired conservation outcomes, constraints are factors that limit the range of management actions that can be applied, external drivers are factors beyond the control of decision-makers, and submodels are ways of predicting outcomes in the conceptual model. Table 3.1.1 and section 4.1 describe the evolution of the decision frame.

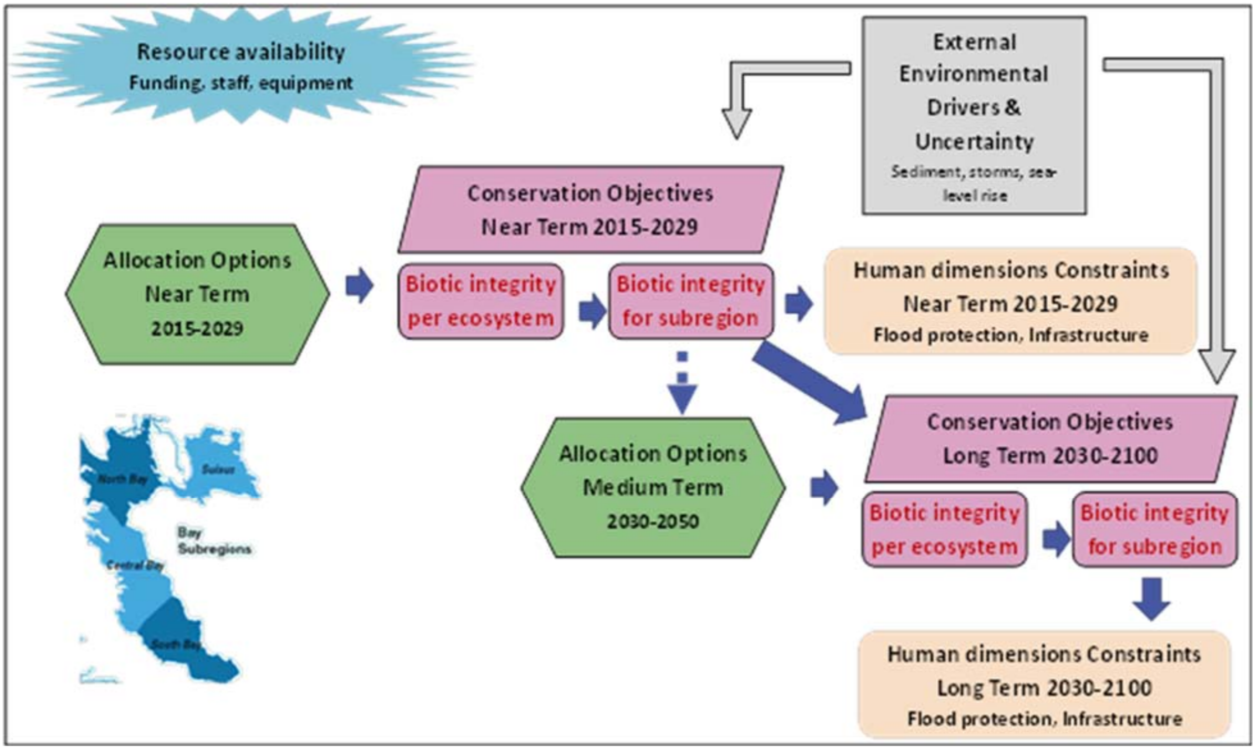


Table 3.1.2. Classification of Bayland ecosystems.

Classification of six Bayland ecosystems where actions could be applied for conservation of the SF Bay Estuary.

Estuarine ecosystems

5) **Sub-tidal and intertidal mudflats**

Estuarine subtidal: Those estuarine ecosystems within substrate that is permanently flooded by tidal water

Estuarine intertidal mudflats: Sedimentary intertidal habitats created by deposition in low energy coastal environments, particularly estuaries and other sheltered areas. Their sediment consists mostly of silts and clays with a high organic content.

6) **Tidal marsh**

Marsh found in estuaries where the flooding characteristics are determined by the tidal movement of the adjacent estuary, sea or ocean. According to the salinity of the flooding water, freshwater, brackish and saline tidal marshes are distinguished. Respectively, they may be classified into coastal marshes and estuarine marshes. They are also commonly zoned into lower marshes (also called intertidal marshes) and upper or high marshes, based on their elevation with respect to the sea level. They may be classified by salinity, tide range, and geomorphic setting.

7) **Managed/diked marsh and ponds**

Diked marshes and managed ponds (former salt production ponds) are generally managed by owners to provide habitat for waterfowl, shorebirds, and other water birds. Primary management strategies usually involve the manipulation of salinity (from more salty to less salty), the regulation of water levels (draining and flooding). Management of water quality and quantity require regular maintenance of infrastructure (e.g., levees/dikes, water control structures). The intensity of management can have a significant effect on the plants and animals inhabiting managed ponds and marsh.

8) **Upland transition zone**

Estuarine-terrestrial transition zones occupy the boundary between land and sea, from tidal marsh up to the effective limit of tidal influence. These zones harbor unique plant communities, provide critical wildlife support to adjacent ecosystems, and play an important role in linking marine and terrestrial processes. Includes seasonal wetlands (areas where water covers the soil only during the wet season) and vernal pools.

Non-estuarine, upland ecosystems

7) **Migration space**

Includes agricultural lands adjacent to Baylands (primarily found in North Bay) along with upland areas adjacent to any of the estuarine ecosystems. To be considered migration space, the adjacent uplands must have sufficient slope and elevation that would provide some possibility for the upland ecosystem to transition into an estuarine ecosystem with sea-level rise.

8) **Watershed**

A drainage basin or watershed is an extent or an area of land where surface water from rain and melting snow or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join the estuary.

3.2 Identifying and defining conservation objectives (fundamental objectives)

Identifying measurable conservation objectives that reflected the wishes and trade-offs from the perspective of stakeholders was a crucial part of the project to ensure that the recommended allocations would be defensible, guide on-ground decisions, and provide a means for evaluating and adjusting management actions over time via adaptive management. As with the decision frame, conservation objectives were identified and refined in an iterative approach through discussions within the leadership team and with all participating stakeholders. This section summarizes the sequential development of Bayland wide, ecosystem-specific conservation objectives (i.e., those that could apply to a particular estuarine ecosystem anywhere in the SF Bay Estuary). For further details see section 4.2.

By incorporating stakeholder feedback throughout the orientation webinar series, we arrived at a set of Bayland wide conservation objectives and associated focal species and measurable attributes (henceforth, indicators) (Table 3.2.1, and Table 3.2.2). The conservation objectives and indicators were also based on those found in existing multi-ecosystem conservation plans (Table 3.2.3). We summarized the Bayland wide conservation objectives with the following statement:

Perpetuate the physical integrity, functions, biodiversity, and wild populations of estuarine ecosystems, while meeting demands for human health, safety, and well-being.

During breakout sessions at the workshop, subregional teams used the Bayland wide conservation objectives and indicators as a starting point for choosing subregion-specific objectives and indicators. This subregional development is summarized in section 6.1.

Table 3.2.1. Bayland wide focal species by taxon.

Focal species representing biotic integrity of SF Bay estuary. These were based largely on draft focal species for the Bayland Ecosystem and Habitat Goals Update. Species or guilds with an asterisk (*) were ultimately chosen to represent changes in biotic integrity for one or more subregions (see section 6.1). Other species were chosen for inclusion in the subregional decision models but not shown here.

---

1. Birds
    1. Tidal-marsh dependent*: Ridgway's Rail*
    2. Marsh predators: Northern harrier
    3. Ducks
        1. Dabblers in managed ponds* : American widgeon
        2. Divers in managed ponds*: Canvasback
        3. Divers in open Bay*: Scaup
    4. Shorebirds*
        1. Large*: American avocet
        2. Small, breeder*: Western sandpiper
        3. Small, migrant*: Snowy plover*
2. Mammals
    1. Tidal marsh & Diked bayland*: Salt marsh harvest mouse*
    2. Open Bay: Harbor seal*
3. Amphibians*
    1. Freshwater wetlands: Red-legged Frog
4. Invertebrates
    1. Vernal pools: Focal species pending
5. Fish*:
    1. Shallow aquatic*: Pacific herring
    2. Open water: Delta/longfin smelt*
    3. Pickleweed: Marsh longjaw mudsucker
    4. Estuarine lagoon: tidewater goby
    5. Vegetated marsh edge: chinook salmon OR steelhead

Table 3.2.2. Bayland wide indicators of biotic integrity.

Proposed indicators of changes in biotic integrity for each of four estuarine ecosystems in SF Bay, as provided at start of stakeholder workshop. These served as a starting point for selecting subregion-specific indicators within each ecosystem. X = proposed; asterisk (*) = adopted by stakeholders in at least one subregion. Others were adopted that are not shown here (see section 6.1).

Indicator (Change in…)	Subtidal and intertidal mudflats	Tidal marsh	Managed wetlands	Upland transition zone
Acreage dominated by native plants	*	X*		X*
Acreage of high-tide refugia (plant cover) for marsh wildlife				X*
Distribution & acreage of eelgrass beds	X*			
Distribution & acreage of shellfish beds	X*			
Density of invertebrates in seasonal wetlands				X
Diversity index for fish community	X*		*	
Population density of wading birds; Focal species: Ridgway's Rail		X*		*
Population density of large-bodied breeding shorebirds; Focal species: American Avocet	X	X*	X*	X
Population density of small-bodied shorebirds; Focal species: Western Sandpiper	X*	X*	X*	X
Population density of high-salinity specialists; Focal species: terns			X*	
Avian nest survival; Focal species: terns and plovers			X	
Abundance of diving ducks; Focal species: scaup	X*		X*	
Population size of dabbling ducks; Focal species: American widgeon		X*	X*	
Population density of marsh mammals; Focal species: salt marsh harvest mouse		X*	X*	*
Abundance of marine mammals; Focal species: harbor seal	X			

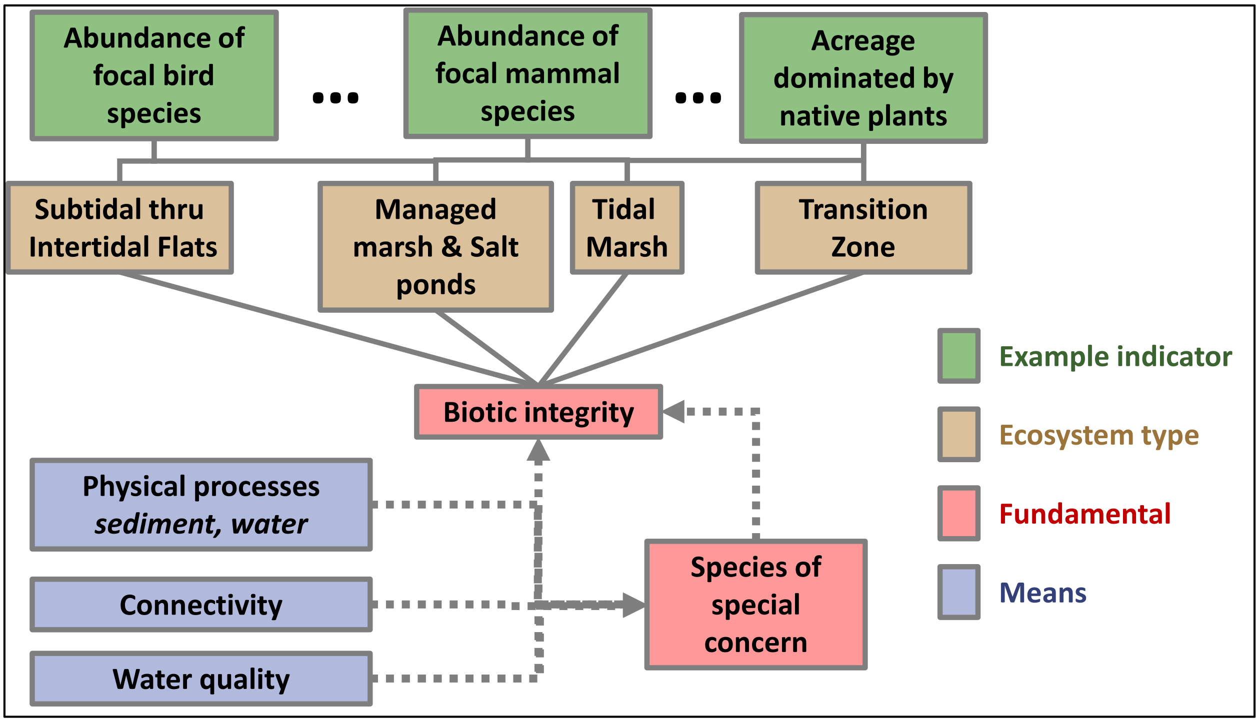


Figure 3.2.1. Final objectives hierarchy.

Diagram showing linkages among conservation objectives (i.e., what we ultimately want to achieve, also known as fundamental objectives) and distinguishing means objectives (i.e., those that affect or influence conservation objectives). Example indicators for biotic integrity are also shown; ellipses (…) represent other indicators not being shown here. This diagram served a basis for developing ecosystem-specific influence diagrams in a later step of the project (Figure 4.5.1).

Table 3.2.3. Ecosystem-level conservation plans for Baylands.

Conservation plans used to inform selection of conservation objectives and associate indicators for CADS Phase 1. BCDC = Bay Conservation & Development Commission; BEHGU = Bayland Ecosystems and Habitat Goals Update; SDM = structured decision making; SFBJV = San Francisco Bay Joint Venture.

Brief name	Full title	Reference
	Multi-ecosystem conservation plans	
2011 SDM Workshop	Collaborative decision-analytic framework to maximize resilience of tidal marshes to climate change	(Thorne et al. 2015)
BEHGU recommendations	Baylands Ecosystem Habitat Goals Update for Climate Change	Unpublished draft, August 2013
BCDC Bay Plan	San Francisco Bay Plan	(San Francisco Bay Conservation and Development Commission 2012)
Bayland Goals	Baylands Ecosystem Habitat Goals.	(Goals Project 1999)
SFBJV Implementation Plan	Restoring the Estuary: A Strategic Plan for the Restoration of Wetlands and Wildlife in the San Francisco Bay Area	(San Francisco Bay Joint Venture 2001)
SFBJV Guidance Document	Conservation Objectives for the San Francisco Bay Estuary as Outlined in Planning Documents of North America's Major Bird Conservation Initiatives	(San Francisco Bay Joint Venture 2004)
	Single-ecosystem conservation plans	
Tidal Marsh Recovery Plan	Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California	(U.S. Fish and Wildlife Service 2013)
Subtidal Goals	San Francisco Bay Subtidal Habitat Goals Report: Conservation Planning for the Submerged Areas of the Bay	(California State Coastal Conservancy 2010)

3.3 Identifying & refining action categories

Developing a suite of options for subregional conservation in the SF Bay estuary posed a significant challenge, given the enormous list of possible conservation actions provided in conservation planning documents (Table Conservation Plans). Although it would be ideal to identify recommended allocations among this list of actions, a feasible compromise was to combine individual actions into categories (hereafter referred to as 'action categories'). Consistent with developing conservation objectives, we first arrived at a set of action categories that could apply anywhere in the Baylands. These were based on draft recommended actions from BEHGU in addition to stakeholder input during the webinar series and workshop. For more details see 4.3.

Table 3.3.1. Bayland wide action categories.

Action categories that could apply to any ecosystem or subregion within the Baylands around SF Bay. These were refined for developing subregion-specific resource (e.g., time and funding) allocation options in each focal Bayland ecosystem (see section 6.3).

7) *Protect acreage*: e.g. conservation easements, land acquisition
8) *Manage sediment* -- e.g. alter dam releases, beneficial reuse of dredge material
9) *Manage/protect species of special concern* -- e.g. predator management, translocation/captive breeding
10) *Manage vegetation community* -- e.g. plant natives, remove / treat against invasives
11) *Manage water levels* -- e.g. change water depth
12) *Manage human disturbance* -- e.g. manage recreation access, reroute transportation corridors
13) *Manage water quality* -- e.g. reduce contaminant inputs, regulate salinity

3.4 Developing future scenarios and resource allocation options

The stakeholders agreed when defining the decision frame (see section 3.1) that the type of decision to be informed through CADS is a resource allocation question – *how do we best use available resources to achieve conservation objectives?* Many of the conservation concerns in SF Bay can be addressed by securing adequate resources (e.g., funding, equipment, and staff time) and allocating them appropriately. Allocating resources is not an end until itself but a means to achieving the conservation objectives. To solve this decision question, we needed to identify resource allocation options. Several options were discussed during the webinar series. This section describes the approach we arrived at to allocate resources. Section 4.4 gives more details on how the approach evolved through stakeholder input.

There were two steps to developing allocation options: 1) developing alternative future scenarios for environmental conditions (e.g., extreme storms, sea level rise) and for resource availability (e.g., time and funding); and 2) allocating resources among action categories and ecosystems under each of the scenarios. At the workshop, participants were provided with a guide for working through these steps within their subregional breakout groups (see Appendix D-2).

3.4.1 Scenario development

Together with all the participants at the stakeholder workshop, we developed two environmental and resource-availability scenarios for the near-term outcome horizon (2015-2029) and two for the long-term outcome horizon (2030-2100). The scenarios were used to form a "rosy" and a "not-so-great" outlook for the future time horizons as basis for developing two respective resource allocation options that take into account what the future is expected to bring (Table 3.4.1 and Table 3.4.2).

Table 3.4.1. Future scenarios for environmental conditions.

Two alternative scenarios for environmental conditions affecting estuarine ecosystems during two time horizons in SF Bay. These were developed in plenary during the first day of the stakeholder workshop.

Rosy	Not So Great
Near-term (2015-2029)	
Extreme storm events spaced out in time and not coinciding with big high tides	Multiple (2-3) extreme storms hitting at once & coinciding with king tides (like in 1986)
Expected levels of sea-level rise[a] (+40 cm from current) and sediment	Expected levels of sea-level rise (+40 cm from current) and sediment
Infrastructure (e.g., levees, dikes) maintained	Infrastructure (e.g., levees, dikes) fails
Temperature, salinity, DO, and pH regimes okay for native aquatic biota	High temperature impacts on native aquatic biota; Ocean acidification
Long-term (2030-2100)	
Extreme storm events spaced out in time and not coinciding with big high tides	Multiple (2-3) extreme storms hitting at once & coinciding with king tides (like in 1986)
Optimistic sea-level rise (+55 cm from current) and low sediment availability	Pessimistic sea-level rise (+165 cm from current) and low sediment availability
Infrastructure (e.g., levees, dikes) maintained	Infrastructure (e.g., levees, dikes) fails
Temperature, salinity, DO, and pH regimes okay for native aquatic biota	High temperature impacts on native aquatic biota; Ocean acidification

[a] Sea-level rise scenarios in this table are based on Stralberg et al. (2011).

Table 3.4.2. Future scenarios for resource availability.

Two alternative scenarios for resource availability during the near-term (2015-2029) and longer-term (2030-2050) management horizons for conserving estuarine ecosystems of SF Bay, developed collaboratively with all participants at the stakeholder workshop.

Rosy: 2-3 x current resources

- Approximately $250M-$1.25B
- Army Corps of Engineers and dredging community conduct beneficial reuse of sediment
- Silicon Valley leadership in conservation of Baylands
- Many conservation funds awarded
    - San Francisco Bay Restoration Authority ballot measure $15M/yr
    - State Water bond $75M
    - Funding to deal with threats from sea-level rise
    - Blue Carbon funding, habitat markets
    - San Francisco Bay EPA Authorization (Currently Spear-Feinstein)
    - Earmarks return
    - Funding for increased training, knowledge, collaboration
    - EPA water quality funds
    - Next set of state resource bonds

Not So Great: less than double the current levels

- Wildlife Conservation Board and State Coastal Conservancy bond funding run out
- Budget decreases
- Everything is litigated
- Hiring freezes
- No travel
- Congressional gridlock
- No collaboration

3.4.2 Resource allocation options

Each subregional group developed two resource allocation options for the near-term (2015-2029) and longer-term (2030-2050) management horizon, for a total of four allocation options. For each management horizon, they developed an allocation that assumed a Rosy future and another that assumed a Not-So-Great future scenario (Table 3.4.1 and Table 3.4.2). The groups started with an allocation template (Table 3.4.3), which they then modified as needed to accommodate any changes to the action categories and ecosystems for their subregion (see sections 6.1 and 0). They then collaboratively filled in percentages of resources to be allocated toward each combination of action category and ecosystem so that the total added to 100.

Table 3.4.3. Final template for developing resource allocation options.

Template for creating options for allocating resources for conserving the SF Bay Estuary. Stakeholders working in subregional breakouts were asked to provide one allocation option for each of two management horizons under one of two possible scenarios for environmental conditions and resource availability in their subregion. A percentage (0-100%) must be entered for each combination of action category and ecosystem, and the percentages must add to 100% when summing all the combinations. Subregional teams modified this template to accommodate their revised action categories and focal ecosystems.

Subregion: North Bay, Suisun Bay, Central Bay, or South Bay

Environmental scenario: Rosy or Not-So-Great

Resource scenario: Rosy or Not-So-Great

Management horizon: 2015-2029 or 2030-2100

	Bayland ecosystem					
Action category	Sub-tidal and intertidal mudflats	Tidal marsh	Managed or diked marshes & ponds	Upland transition zone	Migration Space	Watershed
Protect acreage						
Manage sediment						
Manage individual wildlife species						
Manage vegetation for multiple species						
Manage water						
Manage human disturbance						

3.5 Making predictions about drivers and conservation outcomes

Quantitative predictions of outcomes for the conservation objectives, in terms of effects of allocation options and external drivers (i.e., factors beyond the control of participating stakeholders), is a crucial step toward identifying an optimal resource allocation for each subregion. There were four steps toward making these predictions:

1) Develop a simple conceptual model linking allocation options and external drivers (e.g., extreme storms) to the conservation objectives within each subregion.

2) Expand the conceptual model as an ecosystem-specific influence diagram for each subregion showing how the conservation objectives are affected by action categories and external drivers via intermediate drivers.

3) Choose measurable attributes and binary levels (e.g., stable/increasing vs. decreasing) for the conservation objectives, intermediate drivers, and external drivers for each subregion.

4) Assign probabilities to possible outcomes for the conservation objectives and how they are affected by external drivers and a chosen resource allocation, sometimes via intermediate drivers.

Each step was carried out in an iterative fashion with step 1 being completed during the orientation webinar and steps 2 - 4 starting during the stakeholder workshop and completed through the subregional team meetings during and after the stakeholder workshop. This section summarizes each step, and more details are provided in section 4.5.

3.5.1 Developing influence diagrams

An influence diagram shows relationships between categories of actions, external drivers, intermediate drivers, and indicators representing conservation objectives for each ecosystem of a subregion (Figure 3.5.1). Developing these diagrams was an essential step toward making predictions needed to eventually recommend a resource allocation for a given subregion. A goal for the subregional breakouts during the stakeholder workshop was to develop an influence diagram for each of the four focal estuarine ecosystems. At the start of the workshop, participants were provided a draft influence diagram showing linkages between proposed sets of external drivers, intermediate drivers, and indicators for each of the four estuarine ecosystems (Figure 4.5.1). As these were not yet customized for particular subregions and time horizons, they were meant to be initial starting points for revision during breakout sessions. The subregional teams were encouraged to use existing conservation plans for their own subregion (e.g. Suisun plan[3], South Bay Salt Pond Restoration Plan[4]) and for particular Bayland ecosystems (Table 3.2.3) when developing their ecosystem-specific influence diagrams. When developing their influence diagrams, stakeholders only included drivers that have a high potential impact on the conservation objectives. This ensured that it would be

[3] U.S. Bureau of Reclamation, U. S. Fish and Wildlife Service, and California Department of Fish and Wildlife 2014
[4] U.S. Fish and Wildlife Service and California Department of Fish and Game 2007

feasible to make predictions for all the combinations of factors using expert elicitation (see 3.5.3 below).

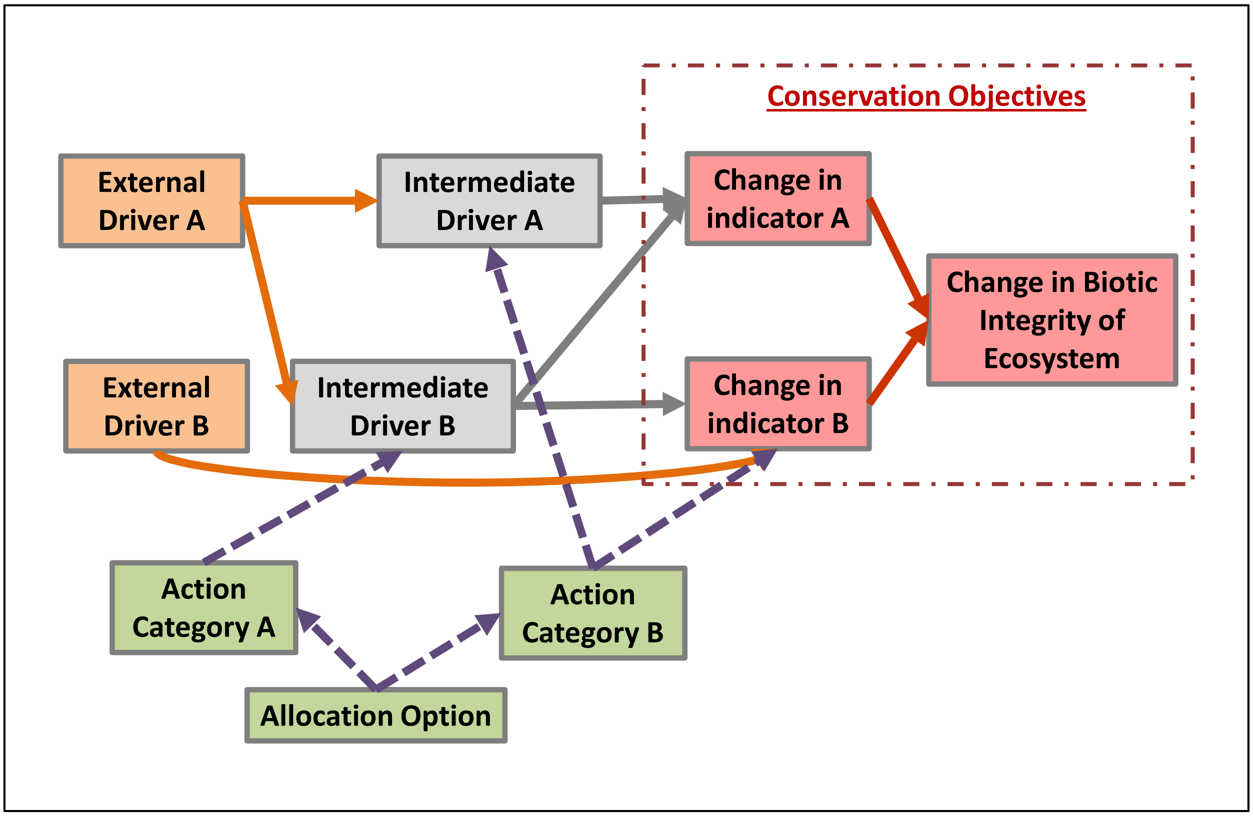


Figure 3.5.1. Generic example influence diagram for a particular ecosystem.

Generic influence diagram showing example of links between external drivers (e.g., extreme storms), action categories, intermediate environmental drivers (e.g., sediment supply) and indicators of biotic integrity (e.g. change in shorebird abundance). Change in biotic integrity as a whole can be a function of multiple indicators, and these are collectively the ultimate desired outcomes of a conservation effort (aka fundamental objectives). Including external and intermediate drivers allow us to explicitly include particular sources of uncertainty regarding the outcomes of the conservation objectives. The allocation option dictates what percentage of resources are dedicated to each action category.

3.5.2 <u>Choosing measurable attributes and thresholds</u>

Identifying attributes and thresholds for indicators, intermediate drivers, and external drivers (henceforth, factors) for a subregion was a necessary step before making predictions about how different resource allocations (e.g., where we focus time and funding) ultimately lead to conservation success. Following the provided guidelines during breakouts at the workshop (see Appendix D-1) and working from a draft set of factor attributes (Table 3.2.2 and Figure 4.5.1), subregional teams selected an attribute for each factor. Working with a decision analyst, subregional teams ensured that each attribute was defined clearly enough so that it could be measured or predicted quantitatively (e.g., change in numbers of dabbling ducks in managed ponds and diked marsh ecosystems).

3.5.3 Assigning probabilities to attributes

Early in the webinar series when framing the decisions, stakeholders were adamant that we needed to account for uncertainties about external environmental drivers (e.g., extreme storms, sediment supply) and how these drivers would alter the ability to achieve conservation objectives through management actions. Because of this strong need to account for uncertainties we chose to use a Bayesian decision network (BDN; see section 3.7.1), which explicitly incorporates these sources of uncertainty when providing recommended allocation options. Subregion-specific BDNs (henceforth, subregional decision tools; Appendix I) were structured based on the respective subregion's ecosystem-specific influence diagrams, including linkages between resource allocation options, external drivers, and conservation objectives. To provide a recommended allocation, each subregional decision tool required as input the probabilities for levels of external drivers and for the effects of external drivers and allocation options on the conservation objectives. It is through these probabilities that uncertainties were accounted for when arriving at recommended resource allocations.

Predictive models would ideally be used to populate the subregional decision tools, but in our case there were no such models that provided the probabilities we needed. For example there are predictive models for future sea-level rise at the scale of subregions, but there are no probabilities associated with these projections. In the absence of needed predicted probabilities, we used an expert elicitation process to make quantitative predictions for factors in the subregional decision tools. In summary, the elicitation process entailed asking stakeholders to individually provide a probability for each external driver and probabilities for the effects of external drivers (e.g., resource availability) on the conservation objectives (sometimes via an intermediate driver like sediment supply).

Completing the elicitation process was perhaps the most challenging step of the project, but making quantitative predictions is critical for identifying a recommended allocation based on a decision analytic approach. Taking this quantitative step added a level of transparency, objectivity and justification for the recommended allocations, in that it forced stakeholders to be clear and explicit about their assumptions about how focal ecosystems would respond under different scenarios for management actions and external drivers. Furthermore, incorporating probabilities in the decision tools allowed us (in a later step of the project) to determine expected improvements in performance of conservation objectives if the uncertainties were resolved through further research and analysis (see section 3.7.2 below). Without these elicited probabilities, we would not have been able to account for uncertainties in the recommendations explicitly nor could we quantify the value of resolving the uncertainties.

3.6 Identifying & quantifying trade-offs

It became clear during the webinar series (Table 4.6.1) that tradeoffs between the two outcome horizons (henceforth, temporal tradeoffs) and among the four estuarine ecosystems (henceforth, ecosystem tradeoffs) were of great importance to the stakeholders. Starting with the near-term (2015-2029) horizon, stakeholders within the subregional teams were then asked to quantify how they value possible outcomes regarding biotic integrity in each of the focal estuarine ecosystems (see Appendix D-4 and Appendix G). A best-case scenario where biotic integrity of all ecosystems was given a fixed score of 100, and a worst-case scenario where biotic integrity of all ecosystems was decreasing was given a fixed score of 0. Using these extreme scenarios and scores as reference, stakeholders were asked to assign a score between 0 and 100 for all of the remaining possible changes in biotic integrity among the focal estuarine ecosystems. For example, they were asked how they would value on a scale of 0 to 100, with 0 being the worst case and 100 being the best case, a scenario where biotic integrity of tidal marsh is decreasing but the biotic integrity of the remaining estuarine ecosystems is stable or increasing (Table 3.6.1). This set of values (henceforth, utilities) represented the ecosystem tradeoffs for the near-term from the perspective of each stakeholder.

North Bay and South Bay teams completed the long-term portion of their subregional decision tool. Stakeholders in each of these subregions repeated the process above for quantifying ecosystem tradeoffs during the long-term outcome horizon. These subregional groups also quantified their temporal tradeoffs by giving utility values for possible scenarios regarding outcomes in each of the two outcome horizons, and this was done separately for each ecosystem (Table 3.6.2). The elicited utilities were later used within a decision analytic tool (see section 3.7.1) to determine the relative expected conservation performance (formally, expected utilities) of the resource allocation options. Utility values were elicited independently from each stakeholder as part of a larger elicitation process that also asked them to assign probabilities to outcomes (see section 3.5.3 above).

Table 3.6.1. Example table for eliciting ecosystem tradeoffs.

Example table showing method for eliciting tradeoffs among estuarine ecosystems during the near-term (2015-2029) in South Bay. Shaded cells indicate pessimistic scenarios for the focal ecosystems. The utility value for the best-case and worst-case scenarios was set to 100 and 0, respectively. For description of the biotic integrity attribute see section 4.5.2, and for selected indicators of biotic integrity in each subregion see section 6.1.

Question for stakeholder: On a scale of 0-100 with 100 being the best possible outcome and 0 being the worst, how would you value each possible outcome in terms of change in biotic integrity for each of the four estuarine ecosystems from 2015-2029?

Utility	Subtidal and intertidal	Tidal marsh	Managed ponds	Upland transition zone
100	No decrease	No decrease	No decrease	No decrease
	No decrease	No decrease	No decrease	Decrease
	No decrease	No decrease	Decrease	No decrease
	No decrease	No decrease	Decrease	Decrease
	No decrease	Decrease	No decrease	No decrease
	No decrease	Decrease	No decrease	Decrease
	No decrease	Decrease	Decrease	No decrease
	No decrease	Decrease	Decrease	Decrease
	Decrease	No decrease	No decrease	No decrease
	Decrease	No decrease	No decrease	Decrease
	Decrease	No decrease	Decrease	No decrease
	Decrease	No decrease	Decrease	Decrease
	Decrease	Decrease	No decrease	No decrease
	Decrease	Decrease	No decrease	Decrease
	Decrease	Decrease	Decrease	No decrease
0	Decrease	Decrease	Decrease	Decrease

Table 3.6.2. Example table for eliciting temporal tradeoffs.

Example table showing method for eliciting tradeoffs among estuarine ecosystems during the near-term (2015-2029) in South Bay. Shaded cells indicate pessimistic scenarios for the outcome horizons. The utility value for the best-case and worst-case scenarios was set to 100 and 0, respectively. For description of the biotic integrity attribute see section 4.5.2, and for indicators of biotic integrity see Table 5.4.1.

Question for stakeholder: On a scale of 0-100 with 100 being the best possible outcome and 0 being the worst, how would you value each possible outcome in terms of change in biotic integrity during each of the outcome horizons (2015-2029 and 2030-2100)?

Utility	Near-term (2015-2029)	Long-term (2030-2100)
100	No decrease	No decrease
	No decrease	Decrease
	Decrease	No decrease
0	Decrease	Decrease

3.7 Identifying recommended resource allocations

Following input from stakeholders during the webinar series (section 4.7), we developed an approach to identify recommended resource allocation options for each of the subregions. This section provides a description of the following steps toward arriving at the recommended allocations:

1) Develop structures of subregional decision tools (section 3.7.1)

2) Populate decision tool with elicited probabilities (section 3.5.3) and utilities (section 3.6)

3) Conduct sensitivity analysis based on the range of elicited values (section 3.7.2)

3.7.1 Subregional decision tools

A Bayesian decision network (BDN) was developed for each subregion based on the respective ecosystem-specific influence diagrams. The BDN was used for determining expected conservation performance (henceforth, expected performance) of each allocation option, and these relative performances were then used to identify a recommended resource allocation for one or more management horizons. A BDN is a decision-analytic tool that can identify a recommended allocation as an output and accepts the following as inputs: 1) allocation options, 2) external drivers, intermediate drivers, indicators, and conservation objectives as factors having uncertainty; 3) predicted probabilities (see section 3.5) for these factors; and 4) values that stakeholders place on conservation outcomes (formally, utility values) (Thorne et al. 2015). A BDN could determine the expected performance (formally, expected utility) for each of the allocation options within a subregion for each management time horizon. The expected performance value was derived from the elicited inputs from stakeholders, namely the probabilities for factor levels (section 3.5.3), and the utility values for the possible combinations of changes in biotic integrity for the focal estuarine ecosystems (section 3.6). The allocation option with a higher expected performance was chosen as the recommended allocation, provided it was robust to uncertainties (i.e., its expected performance remained higher even after exploring the full range of probabilities supplied by stakeholders; see section 3.7.2). Subregional tools were completed for North Bay and South Bay in the near-term (2015-2029) and long-term (2030-2100) outcome horizons, and so they arrived at recommendations for both the near-term (2015-2029) and longer-term (2030-2050) management horizons. The remaining subregional tools were completed for the near-term only.

This decision-analytic approach allows for transparently accounting for potential key uncertainties, based on expert elicitation and/or numerical models, along with trade-offs among conservation objectives from the perspective of stakeholders. Participants at the 2011 workshop, many of which participated in CADS Phase 1, found this decision analytic tool to be useful for them in addressing their decision question in a defensible and collaborative fashion (Thorne et al 2015). During preparation for the orientation webinar series and workshop, the leadership team anticipated that a BDN would be a useful decision-analytic tool for identifying recommended subregional allocations. The orientation webinars and workshop were therefore designed so that intermediate products from these stakeholder events would feed into the BDN and therefore provide subregional recommendations as a key set of products from the project.

3.7.2 Sensitivity analysis

Evaluating the robustness of recommended allocations (i.e., whether they change when exploring the range of probabilities for external drivers and outcomes of allocation options) was an important step toward identifying and justifying a final set of recommendations. The decision analyst worked with the decision tool for each subregion to conduct the sensitivity analysis. The sensitivity analysis began with a baseline, which was represented by the averaged probabilities across all stakeholders participating in a subregional team. The recommendation under averaged probabilities was to use the assume-rosy allocation for all subregions and management time horizons (see section 6.6), and so we tested the robustness of these recommendations by swapping out the averaged probabilities with more pessimistic ones to see if the recommendation would change to the assume-not-so-great allocation option (henceforth, "pessimistic allocation"). In particular, two sets of extreme probabilities were chosen from the expert elicitation. The first set represented pessimistic conditions for the external drivers (e.g., extreme storms and resource availability) (see example in Figure 3.7.1). The second set represented a more beneficial effect of the pessimistic allocation on all indicators of biotic integrity (see example in Figure 3.7.2). We were then able to see if the recommendation would change to the pessimistic allocation under these alternative sets of probabilities.

A recommendation was deemed robust if it remained the assume-rosy allocation even after changing focal probabilities using the methods described above. Otherwise, a recommendation was deemed sensitive to one or more of these sources of uncertainty (e.g., probability of a rosy scenario for extreme storms). We then determined the expected gain in performance (i.e., formally: gain in expected utility) from resolving these sources of uncertainty by using a decision-analytic technique of calculating the expected value of perfect information (Runge et al. 2011).

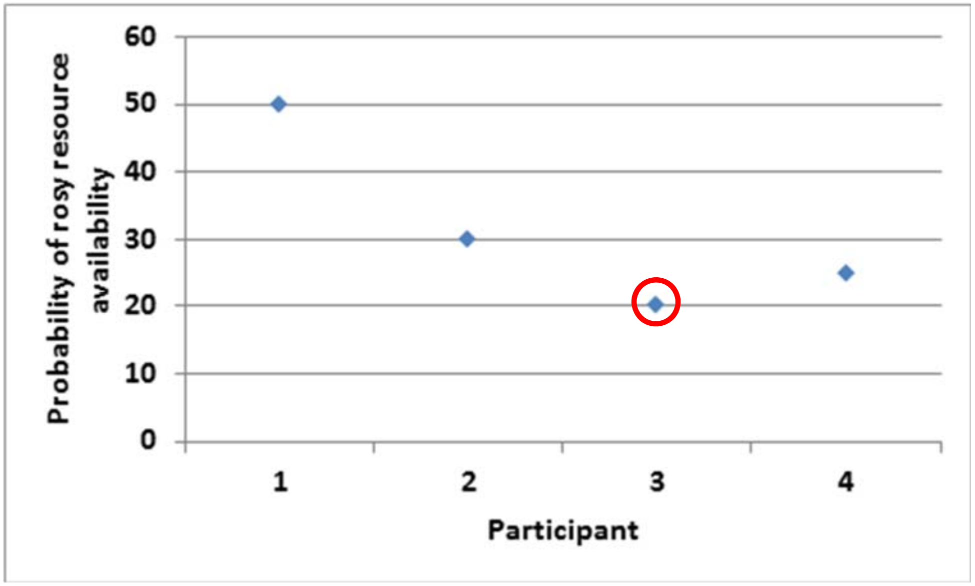


Figure 3.7.1. Example graph showing a pessimistic probability.

Probabilities of resource availability being rosy (i.e., at least double that of current) during the long-term (2030-2100), based on independent inputs from four stakeholders working in South Bay. The circled point is the lowest probability of rosy resources, and was chosen as the pessimistic probability for long-term resource availability in the sensitivity analysis.

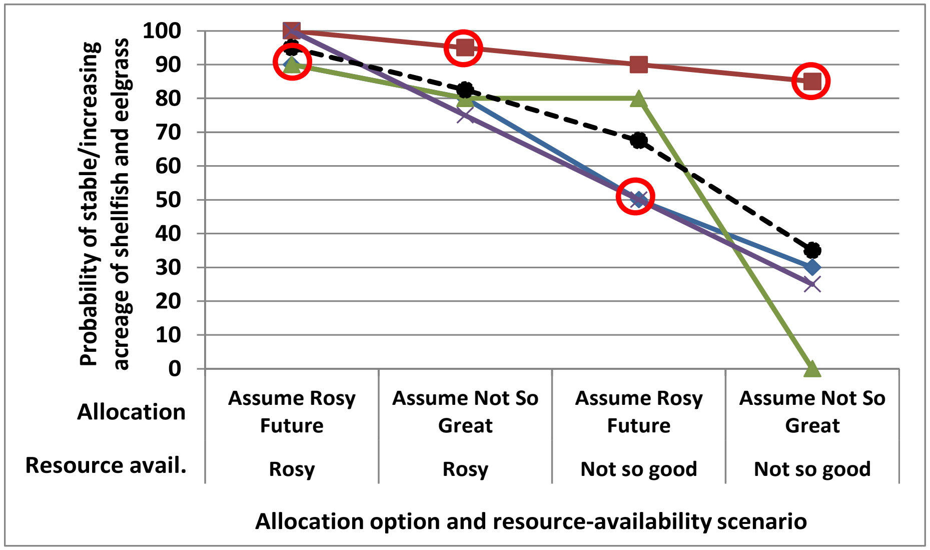


Figure 3.7.2. Example probabilities representing positive effect of the assume-not-so-great allocation.

Probabilities that acreage of shellfish and eelgrass will be stable or increasing in the near-term (2015-2029) in South Bay, as a function of the allocation option and resource availability during the near-term. The probabilities were based on independent inputs from four stakeholders working in this subregion, represented by sets of points connected with solid lines. The circled points are probabilities representing a large positive effect of the assume-not-so-great allocation and a dampened effect of the assume-rosy allocation. These circled probabilities were chosen to evaluate the robustness of the assume-rosy allocation option to this uncertainty about management effectiveness. Closed circles connected by dashed lines were the averaged probabilities across stakeholders (symbols connected with solid lines), which were used for identifying a baseline recommended allocation option.

Chapter 4. Additional details on developing Bayland wide products

This chapter provides additional information about how the steps of CADS Phase 1 were completed, with particular emphasis on how stakeholder input was incorporated. Each section in this chapter is intended as a companion to the sections of Chapter 2 that summarized the final products and the steps used to produce them (Table 2.1.1).

4.1 Framing subregional decisions

Here we provide additional explanations for how the decision frame evolved from project inception through the end of the stakeholder workshop, with a particular emphasis on how stakeholder input was included. The decision frame was developed in a way that it could be adapted for any ecosystem or subregion in the SF Bay Estuary. This is a companion to section 3.1 in the body of the report.

4.1.1 Initial decision framing with project leaders and core team of stakeholders

The leadership team (Table 2.2.1) met several times after the start of the project to revisit the original project goals and reshaped them to ensure that CADS Phase 1 would address the challenges that arose from the 2011 workshop and provide value added beyond the parallel Bayland Ecosystems and Habitat Goals Update (BEHGU). A main concern was that not enough emphasis was placed on producing a product from Phase 1 that would be usable by conservation decision makers such that it could inform their actual decisions. The funded project proposal included the following statement:

"A series of spatially-explicit adaptation decision frameworks will allow not only the SF Bay Joint Venture (SFBJV) to choose among conservation strategies across the Bay but also to directly inform subregional and local managers… for identifying optimal climate adaptation strategies across time and within specific management units while accounting for many uncertainties related to climate change (e.g., sea level rise, extreme events, ecosystem response)."

The above statement emphasizes that the CADS Phase 1 product should inform actual conservation decisions in the Baylands. This statement was used as a basis for drafting an initial decision frame, which described three key elements for subregional decisions.

During a webinar in February 2014[5], we discussed initial draft descriptions of the decisions (Table 3.1.1) with the core team of stakeholders that included not only participants that took part in the 2011 Workshop, but also partners that were leaders in the BEHGU process to ensure compatibility between CADS and BEHGU. The main take-home message from this webinar was that the core team

[5] https://sites.google.com/site/sfbaystructureddecisionmaking/webinars/february

approved of the goals and general approach of CADS Phase 1, with some significant recommendations (Table 4.1.1) that were incorporated in a revised decision frame.

Table 4.1.1. Recommendations for decision framing from core team webinar.

Num.	Recommendation	Response
1	Limit decisions to tidal salt marshes; insufficient tools/info for other estuarine environments	All estuarine environments (existing and potential future) were included in the CADS process, because they are inextricably linked physically and biologically
2	Use 2030 and 2100 horizons to be compatible with BEHGU	We used these horizons to remain compatible with BEHGU
3	Utilize marsh sustainability models	Stakeholders were aware of this and other supporting information when making predictions for their decision tools.
4	Limit allocation alternatives to latest 2050; consider 2050-2100 responses	We used these horizons to remain compatible with BEHGU
5	Account for long-term (i.e., multi-decadal) restoration projects when developing strategies	See #4, above
6	Consider timelines for infrastructure updates when setting timeframes	See #4, above
7	Invest in understanding sediment dynamics, then how that could support long-term marsh sustainability. What can we do to affect sediment supply to tidal marshes?	This source of uncertainty was incorporated within the subregional decision tools, although in South Bay sediment supply was deemed outside managers' control.
8	Consider tradeoffs between saltmarsh species and migratory waterbirds; restoring one habitat type could jeapordize other species	We explicitly considered tradeoffs between ecosystems regarding potential changes in biotic integrity. In almost every ecosystem, we included multiple indicators (e.g. multiple bird guilds) to predict these changes in biotic integrity.
9	For objectives, consider functional groups of migratory birds (e.g., shore birds, divers, breeding vs. wintering) to represent importance of multiple SFB environments & biological communities	see #8 above
10	Beware lumping species into guilds when the individual species respond differently to changing environmental conditions	see #8 above
11	Classify the landscape by habitat type and then assign focal species by habitat type (e.g., upland vs lowland)	see #8 above
12	Use Open Standards for the Practice of Conservation for guidance on narrowing down the number of conservation targets (e.g., similar ecological requirements, similar threats, similar mgt. strategies)	see #8 above
13	Managing watersheds differently to improve sediment dynamics - an alternative we did not consider as part of the 2011 SDM workshop	We included watersheds (Bay tributaries) as part of the resource allocations to help sediment supply in the Bay (removal of dikes, dams etc). We also recognized that flood control channels could be re-designed to “naturally” deliver sediment to the Bay
14	Include as a deliverable an online (interactive) version of the CADS tool that managers can use 20 years from now	In addition to the final report, stakeholders can download all of the quantitative inputs that went into the subregional decision tools along with the decision tools themselves. Using and modifying the decision tools requires some expertise in decision analysis.
15	Put deliverables on climate commons; invite Rebecca to core team meetings	Yes

4.1.2 Revising decision frame during stakeholder-orientation webinars

We held a series of four weekly webinars in April 2014 in preparation for the stakeholder workshop. These webinars provided opportunities for participants to 1) discuss and recommend adjustments to the decision frame; 2) and prepare for the May 2014 workshop where we would apply collaborative decision analysis (CDA) and structured decision making (SDM) (Thorne et al. 2015) to identify recommended conservation allocations. The webinars were run by the leadership team, which was expanded from the original coauthors of the funded proposal to include a second decision analyst and a professional facilitator. Although the focus of the webinar series was to develop intermediate products in preparation for completing subregional decision tools during the workshop, there were also several interactive mini-lectures on SDM so that stakeholders had at least a minimum exposure to the process. During the initial orientation webinar a recent application of SDM in SF Bay (Thorne et al. 2015) was presented. Preparatory materials describing SDM in more depth were also provided but not required.

During the webinar series stakeholders provided many important suggestions for framing the decision, many of which were adopted (Table 4.1.2). In addition stakeholders raised many questions that were addressed by the leaders (Table 4.1.3), which further helped to ensure that the final decision frame would best meet their needs and interests. Evolution of the decision frame is illustrated in Figure 4.1.1.

Table 4.1.2. Stakeholder suggestions adopted for decision framing.

Key suggestions from stakeholders that were raised during the orientation webinar series and then adopted as part of the decision framing for CADS Phase 1.

1) Address uncertainties about hydrodynamics and their effects on the estuary;
2) Include subtidal as one of the focal estuarine ecosystems, as it is inextricably linked to other estuarine ecosystems and is part of the BEHGU;
3) Incorporate results of past conservation planning efforts in the Baylands;
4) Focus on benefits of conservation for ecosystems rather than for humans, and rather include the human dimensions as constraints on the actions; and
5) Consider removal of infrastructure (levees, highways, etc.) as part of the suite of possible conservation actions.
6) Instead of the term ‘strategy’ to describe collections of actions, which has a specific meaning in BEHGU that does not align well with the CADS process, we should use ‘action categories’ when referring to groups of management actions and ‘allocations’ when referring to allocation of resources among the action categories.

Table 4.1.3. Questions from stakeholders on decision framing.

Addressing questions raised by stakeholders during the stakeholder webinar series regarding decision framing for CADS Phase 1.

1) *What will be the spatial resolution of the recommendations for CADS and how can these be applied by decision makers at particular scales?*
   - Recommendations will be summarized at the subregional level but would contain enough detail so that decision-makers working at finer scales (e.g., individual projects or focused on particular segments within subregions) could apply them on the ground.
   - Using a hypothetical example (Figure 4.4.1), we discussed how recommendations could instead be more explicitly fine-scaled as resource allocations among BEHGU segment-scale recommended actions.
2) *How can a recommendation for a subregional-scale allocation be implemented on the ground if the actual decision-makers are operating at finer scales with varying mandates and funding sources?*
   - Products will call for coordination among decision makers working within each of the subregions to translate and implement the recommended subregional-scale allocations.
3) *Will the recommendations from CADS be mandatory or elective?*
   - Recommendations will be purely elective and by no means mandatory, while recognizing that subregional coordination of decision-makers would require changes in the way conservation has been done in most parts of the Baylands.
   - Such subregional coordination would be needed to achieve long-term subregional conservation objectives held by the individual decision makers.
4) *What is the value added of CADS relative to BEHGU?*
   - Whereas CADS will provide recommendations for percentage allocations for particular subregions and for two management horizons (2015-2029 and 2030-2050), BEHGU will provide qualitative recommendations that are spatially but not temporally explicit
   - Whereas CADS will provide recommendations based on a quantified decision tool involving predictions and tradeoffs regarding quantifiable conservation objectives during two outcome horizons (2015-2029 and 2030-2100), BEHGU's recommendations although deliberate and science-based will not arise from a decision-theoretic approach
   - Whereas CADS will provide a foundation for formal adaptive management and conservation, BEHGU will not (for reasons given in list items 1 and 2).
   - Therefore, CADS will quantify expected impacts of the recommendations from BEHGU over multiple outcome horizons and use these projections to recommend ways of allocating resources among the BEHGU actions during two management horizons.
5) *Given that restoration planning has already been done for the next 30 years in Suisun, should we drop this subregion from CADS?*
   - Suisun will be included as one of the four subregions for which resource allocations will be recommended. CADS will use the conservation objectives and recommended actions from the Suisun conservation plan[a] to develop a formal decision tool, upon which the recommended allocations will be based. Although the Suisun plan does provide specific recommendations, there was not a clear process for choosing the recommendations nor were they linked to measurable attributes of objectives. The Suisun plan does, however, call for an adaptive management process that would be easier to implement after having such linkages and other products from CADS.

[a] (U.S. Bureau of Reclamation 2014)

Table 4.1.4. Evolution toward a final decision question.

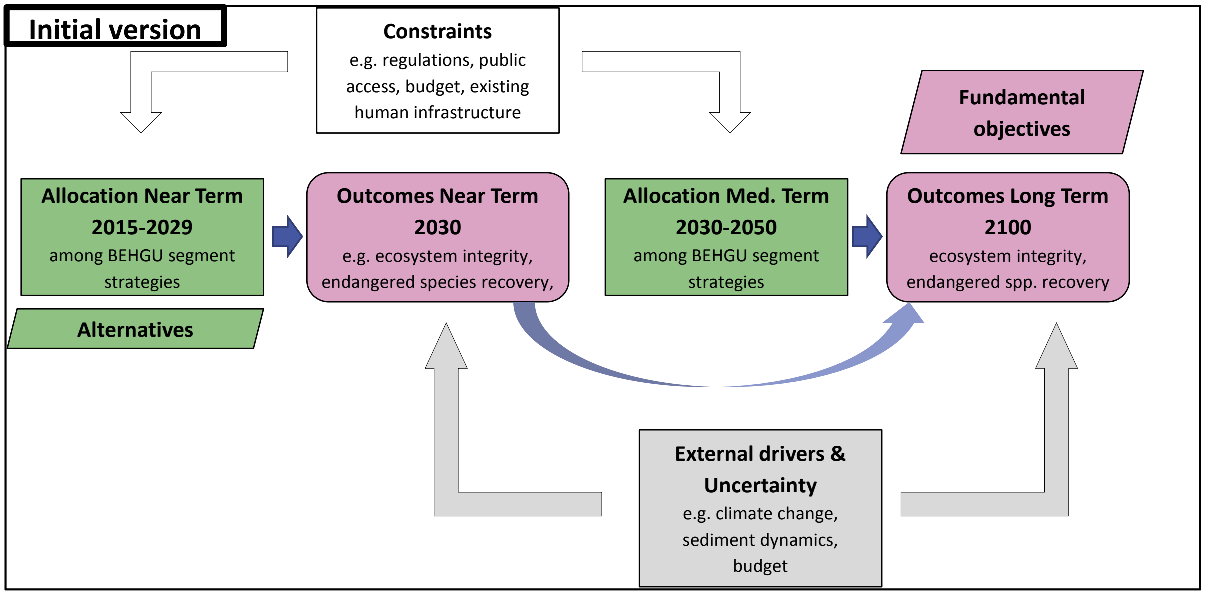
Evolution of the decision question from project inception through the end of the stakeholder workshop. A decision question is a condensed version of the main issues to be addressed within a decision frame. Table 3.1.1 describes the evolution of the decision frame in detail, and Figure 3.1.1 shows this evolution using conceptual models. See section 4.1 for more details.

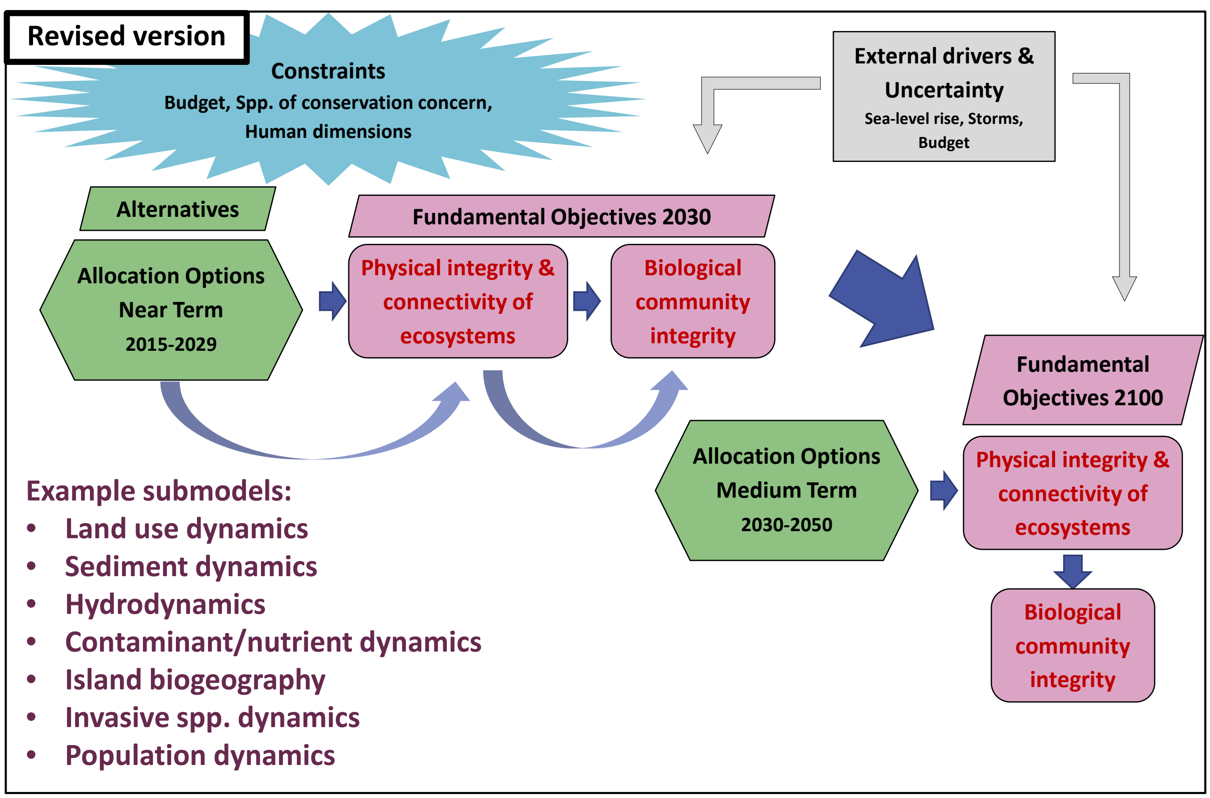
1) *Project goal from funded proposal*: A series of spatially-explicit adaptation decision frameworks for identifying optimal climate adaptation strategies across time and within specific management units while accounting for many uncertainties related to climate change (e.g., sea level rise, extreme events, ecosystem response).
2) *Initial decision question at core team webinar*: What are optimal, actionable conservation and climate adaptation strategies across space & time in SF Bay?
    a. This was simply a condensed version of the project goal, written in question form.
3) *Decision question midway through orientation webinar series*: How should limited funds be allocated across time and space regarding alternative strategies within subregions to conserve San Francisco Bay estuarine ecosystems while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?
    a. This was expanded from the initial version to be more explicit about the type of decisions to address (funding allocation), spatial resolution of the decisions (within subregions), and spatial extent of the conservation objectives (SF Bay Estuary).Stakeholders wanted to add a list of key factors to be considered as part of the CADS effort including key future uncertainties (e.g., climate change) and constraints (e.g. regulations).
4) *Final decision question after stakeholder workshop*: How should limited resources be allocated across time and space toward potential actions within subregions to conserve San Francisco Bay estuarine ecosystems while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?
    a. This was slight rewording to emphasize that additional resources other than dollars limit implementing conservation actions such as staff time and equipment. The term ‘strategies’ was replaced with ‘potential actions’ to avoid confusion with terminology used as part of BEHGU[a].

[a] Bayland Ecosystems and Habitat Goals Update, which will recommend actions that account for future climate change.

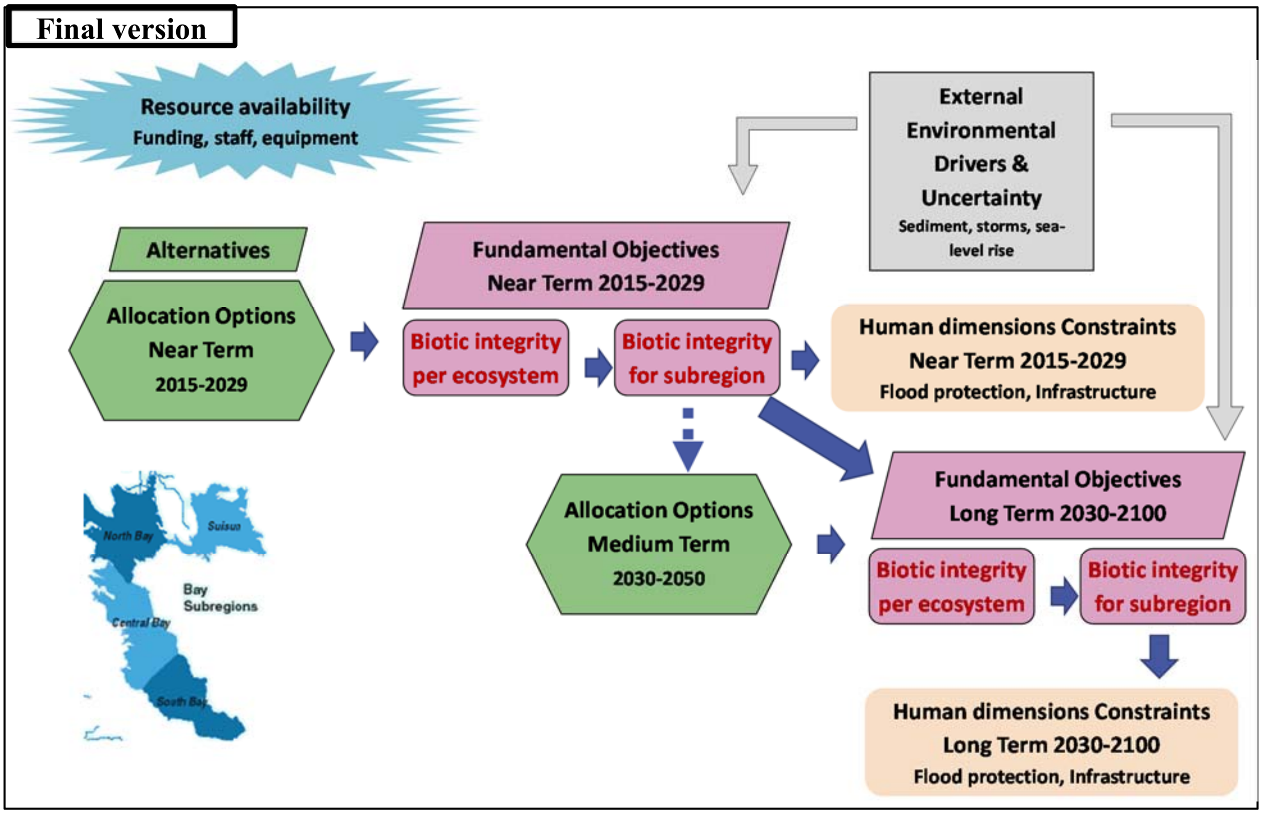
Figure 4.1.1. Evolution toward final conceptual model describing decisions.

Series of diagrams showing the evolution toward a final conceptual model representing decisions to be addressed in CADS Phase 1. Alternatives represent the allocation options for each management horizon, fundamental objectives represent the ultimate desired conservation outcomes, constraints are factors that limit the range of management actions that can be applied, external drivers are factors beyond the control of decision-makers, and submodels are ways of predicting outcomes in the conceptual model. Table 3.1.1 describes the evolution of the decision frame in more detail.





Evolution toward final conceptual model describing decisions, continued.



4.1.3 Finalizing decision frame during stakeholder workshop

Attendees accepted the revised decision frame after reviewing it during plenary, enough to move forward with developing the remaining ingredients needed for the subregional decision tools. Feedback from stakeholders at the end and just following the workshop, however, indicated that the decision frame and the approach to the CADS project should be modified to better fit stakeholder needs (Table 4.1.5). Although we found no consensus after the workshop whether we had framed the decision properly, there was no specific feedback on how the decision frame could be improved in the context of making subregional recommendations for conservation in a way that would satisfy all stakeholders. We concluded that the decision frame was sufficient given the problem presented, i.e. conservation of the SF Bay Estuary. After agreeing on a general description of decisions (i.e., decision frame) that could apply to all subregions, stakeholders were divided into four subregional breakout groups to address the decision frame separately for each subregion (Table 2.2.3).

Table 4.1.5. Stakeholder comments and suggestions on decision framing.

Key comments and suggestions from stakeholders that were raised at the end of the workshop and just following about framing decisions for conservation in the SF Bay Estuary.

1) *The problem being addressed is too big for the time allocated; the approach might be effective on a finer-scale question; focusing on four ecosystems is a lot.*
   - The leadership team believed that by asking questions about conservation of the entire SF Bay Estuary, this would not only inform coordination and allocation of resources in each subregion but also would set the stage for iterating back through the process to inform management at finer scales within the subregions (e.g.,. CADS Phase 2[a]). The CADS Phase 1 process was to collaboratively lay out broad-scale, fundamental conservation objectives that managers working at finer scales can work toward.
   - Starting with a finer-scale management question within the SF Bay Estuary would further the current tradition of acting alone rather than coordination among management partners, which the leadership team felt would be a necessary step for broad-scale conservation of the Estuary.
2) *The workshop was a good opportunity to discuss cross-subregional conservation and then focusing on developing recommendations for each of the four subregions*
   - This comment was in contrast to #1 above, showing the diverse stakeholder perspectives.
3) *Postpone the completion of CADS Phase 1 until the Bayland Ecosystems and Habitat Goals Update is finalized.*
   - The leadership team worked closely with the leaders of the BEHGU process in scheduling the orientation webinars and stakeholder workshop. BEHGU leaders assured us that the timing was right for CADS Phase 1, and that there could be fruitful cross-fertilization between the two efforts. For example, CADS was designed to reveal particular uncertainties about climate-change impacts and management effectiveness that if resolved can improve conservation in the SF Bay Estuary. These key uncertainties could then be highlighted within the BEHGU process to provide more of a focus for the conservation community moving forward.
   - CADS Phase 1 is just a beginning to start addressing conservation questions more explicitly and to build the framework for formal adaptive management. The CADS process is meant to be iterative and to be revisited as more information arises (e.g., through the finalized BEHGU).
4) *The timeline for completing CADS Phase 1 is too ambitious. It has taken two years for many of the BEHGU chapters to come to a mutual understanding on many of the items in the upcoming report and I don't think it is reasonable to expect that a similar process could be replicated by a few webinars and a workshop.*
   - The intent was for CADS to build on and complement, rather than replicate, the BEHGU effort. See also #3 above.
   - We did find, however, that additional stakeholder engagement was necessary beyond the workshop to complete the subregional decision tools (see section 2.2 above).

[a] CADS Phase 2 will develop recommendations for climate adaptation within a focal conservation area, San Pablo Bay National Wildlife Refuge.

4.2 Identifying and defining conservation objectives

Here we provide additional explanations for how conservation objectives and associated measurable attributes were chosen and defined during the webinar series and the stakeholder workshop. Objectives and associated attributes were selected so that they could reflect stakeholder interests regarding any ecosystem or subregion in the SF Bay Estuary. Particular emphasis in this section is on how stakeholder input was included in identifying objectives and attributes. This is a companion to section 3.2.

4.2.1 Initial draft conservation objectives

As preparation for the orientation webinar series leading up to the workshop, the leadership team developed a proposed set of conservation objectives to represent the ultimate desires of stakeholders concerned about estuarine ecosystems of SF Bay. The first step was reviewing existing multi-ecosystem conservation plans for SF Bay (Table 3.2.3) and identifying their stated conservation objectives (Table 4.2.1). We chose conservation plans that were focused on the entire extent of the SF Bay Estuary and emphasized an ecosystem-approach to conservation rather than being restricted to a single species or ecosystem. From a set of six multi-ecosystem conservation plans (Table 3.2.3), we identified 26 unique conservation objectives that served as a starting list for stakeholder consideration. From this starting list, we developed an objectives hierarchy with three tiers: top = dimension (biophysical or human benefits), middle = level of organization (from landscapes to wild populations), and bottom = attributes (e.g., species diversity)

Table 4.2.4 and Figure 4.2.1). This hierarchy provided a basis for the leadership team to propose a subset of 1-4 attributes for inclusion in the project, in an effort to have a tractable number of attributes to evaluate.

4.2.2 Refining conservation objectives during webinar series

Discussions during the webinar series were instrumental in helping to shape the set of conservation objectives and associated measurable attributes (henceforth, indicators) that meet interests and wishes of the stakeholders. These discussions led to selection of Bayland wide conservation objectives from an original set that was based on the review of conservation plans. In a later step of the project, these attributes provided a way for comparing options for allocating limited conservation funds and predicting conservation success over time (see section 3.5).

4.2.3 Finalizing Bayland wide conservation objectives at workshop

As part of a package of materials provided to participants of the stakeholder workshop that followed the orientation webinars (e.g., Appendix C), the leadership team provided a revised version of the objectives hierarchy (Figure 4.2.2) along with a proposed set of indicators representing change in biotic integrity and change in populations for species of special concern for each estuarine ecosystem (Table 3.2.2). These indicators represented the set of desired biological outcomes, which together with the human-dimensions constraints are considered henceforth as the conservation objectives (or more formally, fundamental objectives). Early in the workshop, stakeholders agreed that the conservation objectives for this effort should be specified at the scale of the subregion. Evaluating whether or how the subregional objectives could be rolled up to the entire SF Bay Estuary would be an emergent property of refining the subregional objectives (see section 6.1). Although some stakeholders wanted to identify these cross-subregional objectives in advance, the group was willing to move forward with developing them independently for each subregion starting with the set of objectives provided.

Working with a decision analyst, the stakeholders agreed to simplify their set of conservation objectives by defining an overarching fundamental objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) and long-term (2030-2100) outcome horizons. Although species of special concern reflect concerns other than biotic integrity (e.g., recreation, economy), for simplicity attributes involving these focal species were included as an indicator to represent biotic integrity as a fundamental objective for each estuarine ecosystem. See section 6.1 for the final set of indicators selected by subregion and ecosystem, which were folded into an ecosystem-specific conservation objective for biotic integrity.

Table 4.2.1. Objectives in conservation plans for the Baylands.

Objectives identified from existing conservation plans for the Baylands of SF Bay. They are organized by three hierarchical levels of organization. BCDC = San Francisco Bay Conservation and Development Commission; BEHGU = Bayland Ecosystems and Habitat Goals Update; 2011 Tidal marsh workshop was described by Thorne et al. (2015). SF Bay Joint Venture Plans are not shown, but there were no additional objectives identified in these plans.

Category of consservation objectives for CADS			BEHGU draft August 2013					2011 Tidal marsh workshop	BCDC Plan 2012
Primary	Secondary	Tertiary	SF Bay Region	Suisun	North Bay	Central Bay	South Bay		
Biophysical			X	X	X	X	X	X	X
	Landscapes		X					X	X
		Connectivity	X					X	
		Physical integrity							X
	Ecosystems		X	X	X	X	X	X	X
		Integrity	X	X	X	X	X	X	
		Acreage	X	X	X	X	X	X	X
	Biological		X	X				X	X
		Biological	X	X				X	X
		Terrestrial animals	X	X					
		Marine organisms							X
		Fish							
		Plants	X	X					
	Wild		X	X	X	X	X	X	X
		Demographic	X			X			X
		Genetic diversity	X						
		Species of							X
		Federally						X	X
		Aquatic							X
		Fish	X	X					X
		Terrestrial animals	X	X	X				X
		Waterfowl		X			X		X
		Shorebirds				X	X		
		Waders						X	
		Plants		X	X		X	X	X

Objectives in conservation plans for the Baylands, continued.

Category of consservation objectives for CADS			BEHGU draft August 2013					2011 Tidal marsh workshop	BCDC Plan 2012
Primary	Secondary	Tertiary	SF Bay Region	Suisun	North Bay	Central Bay	South Bay		
Human benefits						X		X	X
	Health & safety					X		X	X
		Flood protection				X		X	X
		Vector-borne disease						X	X
		Air quality							X
		Water quality							X
	Transportation, infrastructure								X
	Non-medical well-being								X
		Recreation						X	X
		Economics							X
		Passive enjoyment							X
		Climate-change mitigation							X
		Urban/residential satisfaction							X

Table 4.2.2. Stakeholder suggestions on choosing attributes for conservation objectives.

Key suggestions from stakeholders that were raised during the orientation webinar series and following the workshop about choosing measurable attributes representing conservation objectives in the SF Bay Estuary. Many of these were adopted by the subregional working groups (see section 6.1).

5) *Include functionality, processes, sustainability, connectivity, and resilience as attributes of ecosystems rather than focusing on just "diversity" of ecosystems.*
   - This suggestion was adopted
   - Connectivity is not only important on its own right but also is an influential factor for objectives related to wildlife species populations and biological communities.
   - We would therefore need to take this relationship into consideration when selecting conservation objectives that are ideally not correlated.
   - Instead of "species diversity" an attribute for "biological community integrity" could be constructed based on relative abundance and species richness for one or more of the following species groupings: functional guilds (e.g., insectivores), taxa (e.g., wading birds), and/or indicator/umbrella species (e.g., Ridgway's Rail).
   - Together these revised attributes projected over the long-term would represent the sustainability and resiliency of estuarine ecosystems.
6) *When quantifying wildlife populations use density instead of abundance, use trends instead of static estimates, and use intrinsic rate of population growth (lambda) for indicator species*
   - This suggestion was partly adopted. Trends in abundance were used for most focal species as attributes of biotic integrity in the subregion-specific ecosystems.
7) *Use species guilds as developed for BEHGU*
   - We used the BEHGU guilds when putting together the initial list of focal species (Table 3.2.1), many of which were used to represent biotic integrity in the subregion-specific ecosystems.
8) *Consider elevation gradient, accretion potential, and sediment delivery as metrics of marsh sustainability in the face of sea-level rise*
   - These were incorporated as means objectives that influence biotic integrity (fundamental objective; Figure 3.1.1)
9) *Rather than using "sizes of ecosystems" as an objective, use acreages providing specific functions such as refugia, nesting, or foraging.*
   - Acreages of each ecosystem type itself are not fundamental objectives on their own without considering the spatial distribution in a subregion and physical quality/condition of the ecosystems.
10) *Instead of salt marsh harvest mouse, use species that are easier to study and monitor, e.g. river otter*
    - Some of the subregional groups included mammal species other than salt marsh harvest mouse (e.g., shrew), but all of them included salt marsh harvest mouse to represent biotic integrity of tidal marsh and/or managed wetlands.
11) *Instead of Ridgway's Rail (which is absent from Suisun) use song sparrow subspecies and/or black rail, which are found throughout the SF Bay*
    - This suggestion was adopted for Suisun.
    - Some of the remaining subregional groups included marsh bird species in addition to Ridgway's Rail to represent ecosystem integrity of tidal marsh and/or upland transition zone.
12) *Include additional upland invertebrate indicators beyond those found in vernal pools*
    - This suggestion was not adopted; only vegetation and wildlife were included as attributes of biotic integrity in the upland transition zone where vernal pools occur.
13) *Consider additional invasive plant species that affect ecosystems.*
    - Subregional groups incorporated reduction of invasive plants as a means objective for improving acreage dominated by native plants in one or more ecosystem.

Stakeholder suggestions for choosing attributes for conservation objectives, continued.

14) *Indicator species should be chosen on a subregional basis rather than choosing them to fit all subregions.*
    - This suggestion was adopted.
    - Although it would be ideal to have a common set of focal species and attributes across subregions, each subregion has a unique set of stakeholders and assemblage of species along with threats to their populations. A recommendation going beyond CADS Phase 1 is to consider scaling up the conservation objectives to the level of the entire SF Bay Estuary. To do this, we first needed to identify what the attributes are for each subregion and see how they could be scaled up.
2) *Expand the definition of living shoreline under the description of the subtidal and intertidal mudflat ecosystem to include other important species besides oyster and eelgrass.*
    - We revised the definition for subtidal and intertidal mudflat ecosystem to avoid an exclusive list of focal species (Table 3.1.2).

Table 4.2.3. Questions from stakeholders about conservation objectives and attributes.

Addressing questions raised by stakeholders during the stakeholder webinar series regarding the selection of conservation objectives and associated measurable attributes to describe biotic integrity of the SF Bay Estuary.

1) *What is "diversity of physically fit ecosystems" (*Figure 4.2.1*)?*
    - We recognized this was a poor descriptor for this attribute and replaced it with "'physical processes" and "sizes of estuarine ecosystems" (Figure 4.2.2).
    - We proposed using the following factors to represent ecosystem-specific integrity and diversity: total acreage, geomorphology, hydrodynamics, sediment dynamics, water quality, sediment quality, acreage of native land cover, and a connectivity index.
2) *Second, how is "species of conservation concern" defined here?*
    - Species that are 1) listed or candidate for listing as threatened or endangered at state or federal level; or 2) species of particular importance for recreation (e.g., waterfowl for birdwatchers and hunters).
3) *Would it be useful to employ the surrogate species concept when choosing focal species as indicators?*
    - This concept was considered when choosing species that are representative of a focal estuarine ecosystem.
4) *How will the conservation objectives be measured in reality -- satellite imagery and/or ground surveys?*
    - At this stage, we did not know which if any of the attributes would need to be monitored. In one of the last steps of the project, we evaluated expected improvements in performance of the conservation objectives of reducing uncertainty by collecting new information (see section 3.7.2). This value of information cannot be known until completing a collaborative decision-analytic process.
    - Choosing attributes that are measurable with existing data collection methods, however, is preferred.

Table 4.2.4. Hierarchy of Bayland wide conservation objectives.

List of conservation objectives for SF Bay Estuary classified into a 3-tier hierarchy. These were identified as ultimate desired outcomes from conservation actions as described in multi-ecosystem conservation plans for SF Bay (Table 3.2.3). Objectives followed by an asterisk (*) were proposed as a reduced, focal set for subregions to consider. Objectives followed by a plus (+) were ultimately included in one or more subregional decision tools (see section 6.1).

Tier I	Tier II	Tier III
Tier I: Biophysical attributes		
	Landscapes	
		Connectivity+
		Physical integrity & diversity of ecosystems *+
	Ecosystems	
		Integrity+
		Acreage+
	Biological communities	
		Species diversity*+
		Terrestrial animals
		Marine organisms
		Fish+
		Plants+
	Wild populations	
		Demographic rates
		Genetic diversity
		Species of conservation concern*+
		Federally endangered+
		Aquatic organisms+
		Fish+
		Terrestrial animals+
		Waterfowl+
		Shorebirds+
		Waders+
		Plants
Tier I: Human benefits		
	Health & safety	
		Flood protection*+
		Vector-borne disease*
		Air quality
		Water quality*+
	Transportation/Infrastructure*	
	Non-medical well-being	
		Recreation*
		Economics
		Passive enjoyment
		Climate-change mitigation
		Urban/residential satisfaction

Figure 4.2.1. Initial objectives hierarchy.

Initial proposed hierarchy of conservation objectives based on a review of multi-ecosystem conservation plans for the Baylands (Table 3.2.3). The legend indicates the total number of attributes identified in the review. The hierarchy included two dimensions: A) desired biophysical outcomes, and B) human benefits. This hierarchy of biophysical objectives was revised after the webinar.

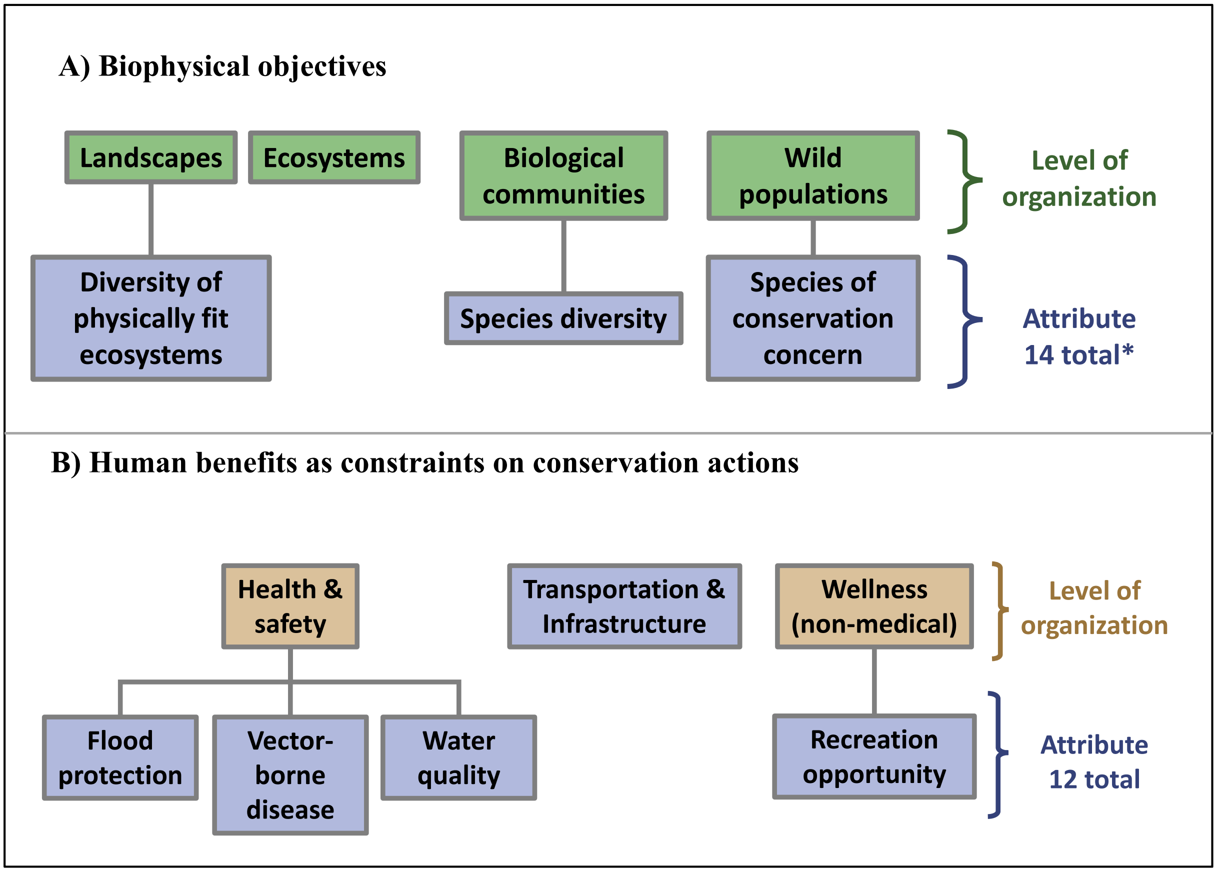
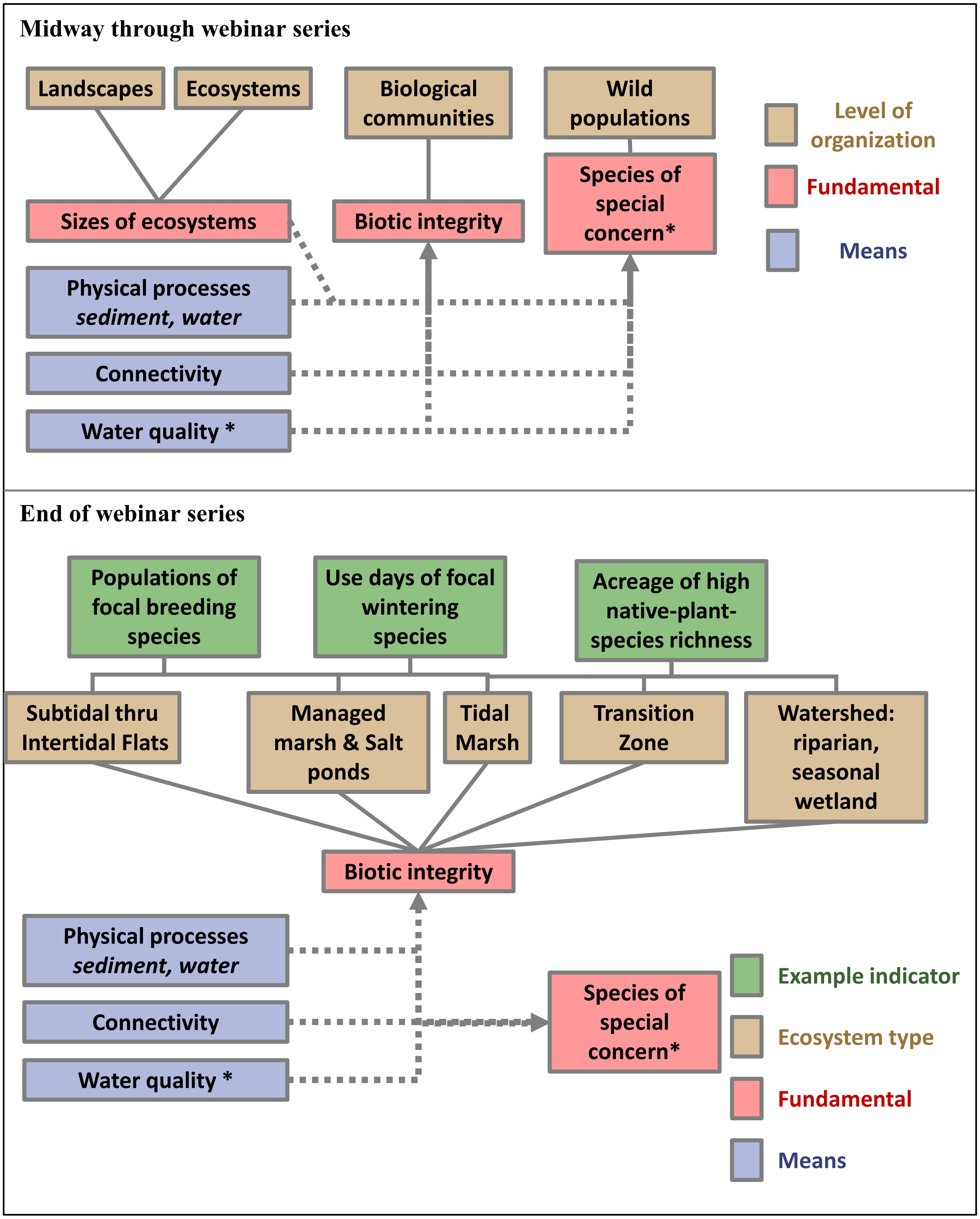


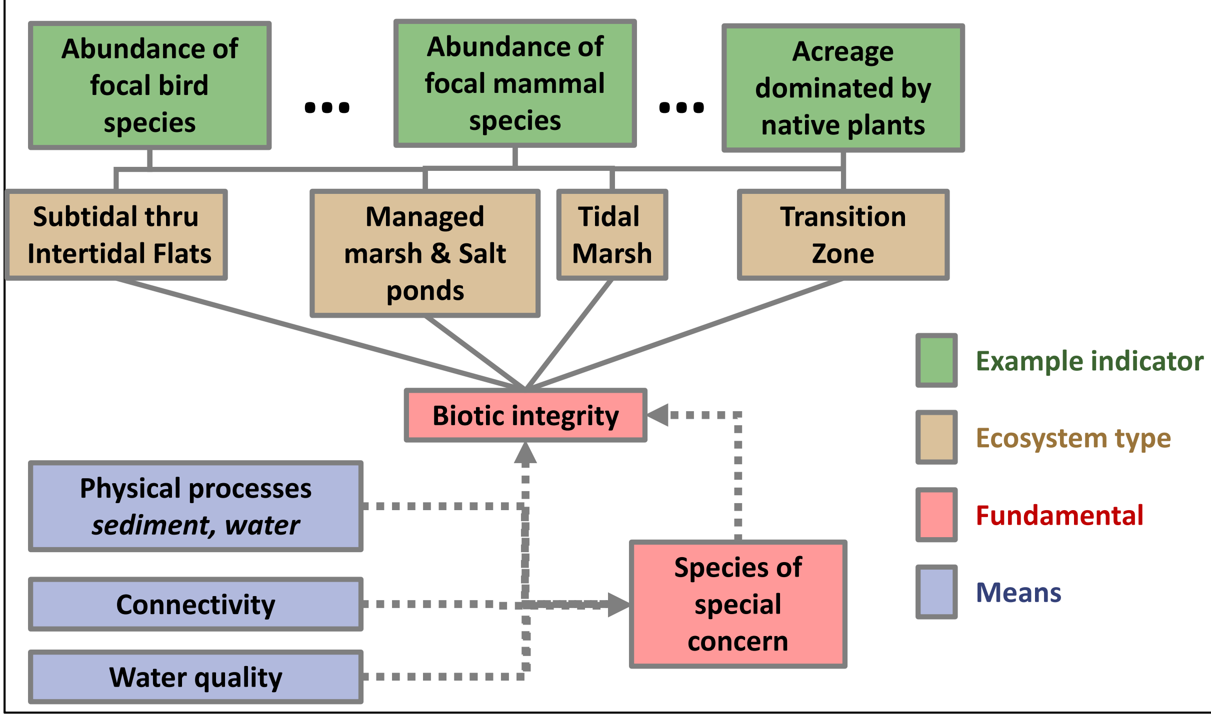
Figure 4.2.2. Evolution of conservation objectives hierarchy with stakeholder input.

Revised diagrams distinguishing means objectives (i.e., those affecting conservation objectives, aka fundamental objectives) from pure fundamental objectives (i.e., those important on their own right and own right only). Example attributes for biotic integrity are also shown.



Evolution of objectives hierarchy with stakeholder input, continued.

Final version



4.3 Identifying & refining action categories

Here we provide additional explanations for how action categories were chosen during the webinar series and the stakeholder workshop. These action categories were structured in a way that they could apply to any ecosystem or subregion in the SF Bay Estuary. Particular emphasis is on how stakeholder input was included in developing the action categories. This is a companion to section 3.3.

Leading up to the orientation webinar series, the leadership team reviewed a draft of segment-level recommended actions from BEHGU to start generating action categories. Although these recommended actions were described with sufficient detail for implementation, there was no a priori categorization of actions. During the review, it became apparent that BEHGU recommended actions varied by ecosystem type. The leadership team, then, as a draft initially identified one action category that appeared to be the most important for each of six Bayland ecosystem types:

1) *Sub-tidal and intertidal*: Protect & restore eelgrass or oyster beds as part of living shoreline
2) *Managed/diked marsh & ponds*: Enhance and protect bird habitat
3) *Tidal marsh*: Restoration and enhancement
4) *Upland transition zone*: Restoration and enhancement
5) *Seasonal wetlands*: Creation, enhancement & management
6) *Watershed*: Management & connectivity

This original set of action categories was refined through stakeholder input during the webinar series and workshop (Table 4.3.2), culminating in a final set of action categories that could be applied to any ecosystem in the SF Bay Estuary (Table 3.3.1). Two of the subregional teams made some adjustments to the classification of action categories after cross-referencing them with subregional recommendations from BEHGU, which became available at the workshop. The final sets of action categories by subregion are described in section 6.2.

Table 4.3.1. Suggestions and questions from stakeholders about action categories.

Addressing suggestions and questions raised by stakeholders during the stakeholder webinar series regarding action categories for conserving the SF Bay Estuary.

Suggestions

1) *Include action categories that affect multiple ecosystems rather than one at a time, e.g. sediment management in watersheds.*
    - In a later step of the project (see section 3.4), allocation options were developed to represent a multi-ecosystem approach.
2) *For tidal marsh we need to include actions for conserving rare animal species (e.g. Ridgway's Rail, salt marsh harvest mouse, and salt marsh wandering shrew) in addition to rare plants.*
    - We rewrote the definition of these ecosystems to avoid a partial list of important species that dwell there.
3) *Include reuse of dredge material/fill as one of the actions under the manage-sediment action category*
    - This suggestion was adopted.

Questions

1) *Why is managed marsh lumped together with managed ponds as one of the focal ecosystems?*
    - Managed marshes may face similar challenges as managed ponds as they relate to sea-level rise (e.g., water level management difficulties with water control structures and levees that may need to be modified in the future). The reasoning here is to consider the management implications of managed systems, even if one is marsh and the other is ponds. As managed systems they face similar issues for long-term conservation.
2) *Why are watersheds included as a focal ecosystem?*
    - Watersheds are important sources of sediment input to the SF Bay Estuary via tributaries, which can help the estuary accrete with sea level rise. Watersheds also provide freshwater inputs that likely affect salinity levels in the Estuary. One of the BEHGU recommendations is taking a watershed approach to addressing climate change impacts in the Baylands.
2) *Should action categories be mutually exclusive? For example, managing species of special concern could involve managing the vegetation community (e.g. treating against invasives) in addition to species-specific actions like translocation.*
    - Action categories were defined such that they would be mutually exclusive, which is important for when developing options for resource allocation. In the case of managing species of special concern, this action category would include none of the vegetation management actions that fall under the manage-vegetation category. Some subregional teams later revised the action categories to better avoid these kinds of overlap and better represent the types of action in their subregion.

Table 4.3.2. Bayland wide action categories.

Action categories that could apply to any ecosystem or subregion within the Baylands around SF Bay.

14) *Protect acreage*: e.g. conservation easements
15) *Manage/protect species of special concern* -- e.g. predator management, translocation/captive breeding
16) *Manage vegetation community* -- e.g. plant natives, remove / treat against invasives
17) *Manage human disturbance* -- e.g. manage recreation access, reroute transportation corridors
18) *Manage sediment* -- e.g. alter dam releases
19) *Manage water levels* -- e.g. change water depth
20) *Manage water quality* -- e.g. reduce contaminant inputs, regulate salinity

4.4 Developing an approach to allocate resources

Here we provide additional explanations for how we arrived at a resource-allocation method during the webinar series and the stakeholder workshop. The approach was structured in a way it could be applied to any ecosystem or subregion in the SF Bay Estuary. Particular emphasis in this section is on how stakeholder input was included in developing the method. This is a companion to section 3.3.

4.4.1 Refinements during webinar series

Early in the webinar series, the focus was on decision framing, classifying ecosystems, identifying conservation objectives, and developing action categories. All of these ingredients were needed in developing an approach to allocate resources. Early in the webinar series we also began discussing hypothetical illustrations (Figure 4.4.1, Figure 4.4.2, and Table 4.4.2) of how resources might be allocated for conserving estuarine ecosystems (Table 3.1.2) in South Bay using the Bayland wide action categories (Table 3.3.1). After receiving feedback during multiple discussions with stakeholders (Table 4.4.1), we arrived at consensus for a method to allocate subregional resources within each of the 6 Bayland ecosystems.

Table 4.4.1. Suggestions and questions from stakeholders about method for allocation.

Addressing suggestions and questions raised by stakeholders during the stakeholder webinar series regarding a method to allocate resources for conserving the SF Bay Estuary.

<u>Suggestions</u>

1) *Include action categories that affect multiple ecosystems rather than one at a time, such as managing sediment in the watershed (this was also discussed in* Table 4.3.1 *above)?*
    - This suggestion was adopted: allocations were split out by action category within each of the Bayland ecosystems for a given subregion (Table 4.4.2), which represents a multi-ecosystem approach.

<u>Questions</u>

1) *Is percent allocation related to the size of the area to which the category of actions should be applied?*
    - The percentage allocated to a particular category of actions would correlate with the footprint of the actions. When comparing two different action categories, however, the percentage allocation will depend on the per-acre cost of applying each of the sets of actions along with the total acreage where they would be implemented. Furthermore, the per-acre cost of a given category of actions may vary across a subregion, and so that variation would need to be considered when developing allocation options.

2) *Should we develop recommendations for each segment, or would rolling them up to the subregion or even the entire Baylands suffice?*
    - After the workshop, the leadership team discussed whether the allocations should be specified at the level of individual segments, for each subregion, and/or for the entire Baylands. It was concluded that subregional scale would be the best scale to use for developing the allocation options. Developing allocation options for each segment of the Baylands (n=20) would be time prohibitive, and these segment-level decisions can be addressed in subsequent efforts lead by local conservation managers (e.g. CADS Phase 2; Chapter 1). Allocating resources among action categories to be applied across the entire Baylands (without specifying subregions) would not be actionable, which was one of the conclusions from Thorne et al. (2015).

Table 4.4.2. Partial template for allocating resources.

Partial template for allocating resources among action categories and Bayland ecosystems within a given subregion of the SF Bay. Only a subset of combinations is shown, and a hypothetical percentage is given for each action-category-ecosystem combination. The percentages must add to 100, and the pattern of percentages reflects how many resources should be directed toward each combination. The hypothetical allocation directs all resources toward protecting acreage and managing sediment in tidal marsh. This template was extended and adopted for the project.

	Bayland ecosystem examples (2 of 8 shown here)		
Action category examples (2 of 7 shown here)	Sub-tidal & intertidal mudflat	Tidal marsh	…
Protect acreage	0	60	…
Manage sediment	0	40	…
⋮	⋮	⋮	
TOTAL	*0*	*100*	

4.4.2 Finalizing approach during workshop

Another ingredient needed for developing allocation options is a basis for having different options. The leadership team proposed at the workshop that we distinguish the two options based on contrasting scenarios for the future in terms of resource availability and environmental drivers. That is, we suspected stakeholders would allocate resources quite differently if they thought the future would bring many resources and no extreme storms than if resources were scarce and extreme storms occurred successively. As part of the workshop information packet, we provided participants for guidelines to develop alternative future scenarios (Appendix D-2). Rather than developing these scenarios independently in the breakouts, the stakeholders wanted to begin developing them as a larger group to ensure so that there was some level of consistency among the subregional groups. Together with all the workshop participants, we developed Rosy and a Not-So-Great scenarios for environmental conditions and for resource availability in the near-term and for environmental conditions in the long-term (Table 3.4.1 and Table 3.4.2). After developing the near-term scenario for resource availability, it was time to begin the breakouts and by then stakeholders were more comfortable building and modifying the scenarios to fit their subregion-specific.

The workshop information packet also included a template allocation table (Table 3.4.3) and instructions on how to construct the allocation options within the table. A suggestion in the instructions was to begin by indicating which of the combinations of action categories and ecosystems would have any resources allocated to them and which would receive zero. The stakeholders could then focus on combinations that would receive some resources, reducing the number of percentages to discuss. Stakeholders worked in their subregional breakouts to collaboratively fill in the allocation percentages for each option, and through this process all the requested allocation options were developed during the workshop. Some subregional teams made minor adjustments to allocation percentages following further discussions after the workshop (see Chapter 4).

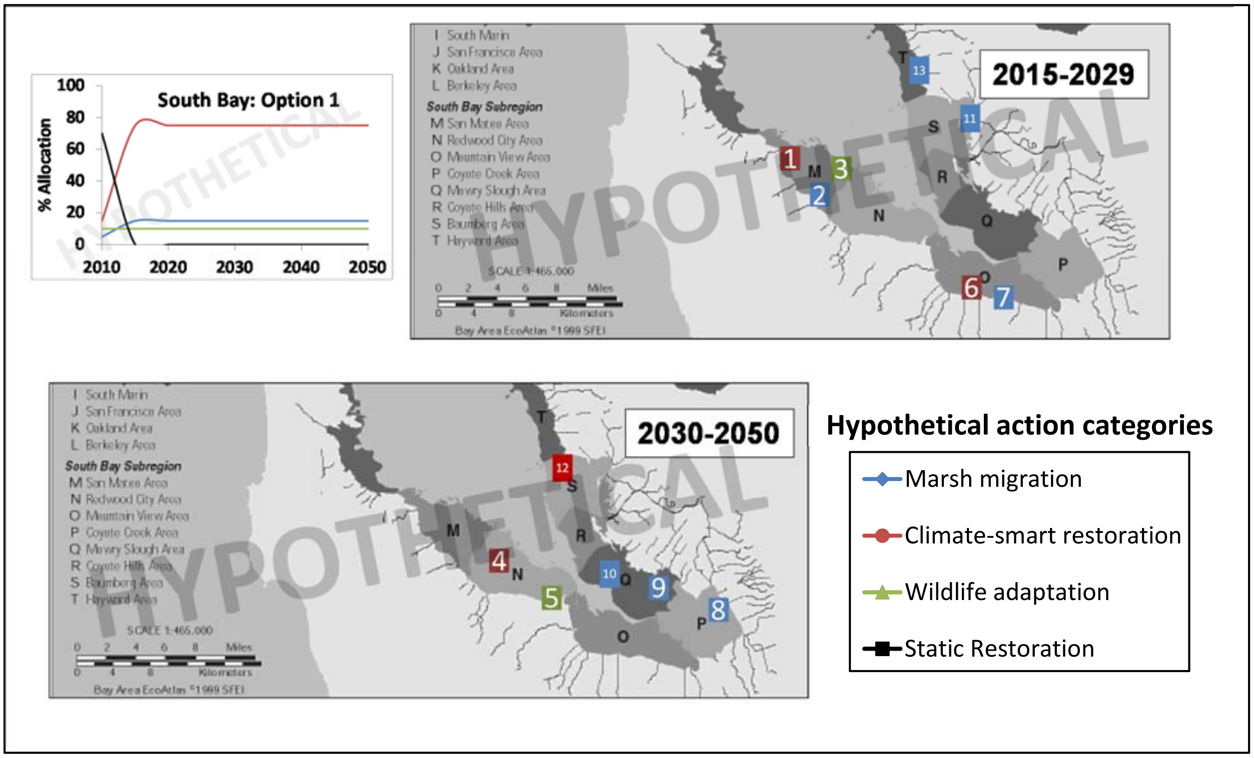


Figure 4.4.1. Translating subregional allocation to segment-level actions.

Hypothetical illustrations of a method for allocating resources within South Bay during each of two management horizons (2015-2029 and 2030-2050) to conserve the SF Bay Estuary over the long-term (2015-2100). The graph was modified from the 2011 workshop (Thorne et al 2015), which here describes temporal resource allocations among four action categories[6] within South Bay. A hypothetical set of 13 actions (shown but not defined here) would be assigned to one action category, and each action would be assigned to a segment within South Bay where it would be implemented (color codes refer to the action categories). The individual actions could be those recommended for particular segments by BEHGU. This method for allocating resources was later refined for particular Bayland ecosystems within a subregion.

[6] Hypothetical action categories are taken from Thorne et al. (2015); we had not yet formulated action categories for CADS when this was discussed early in the webinar series.

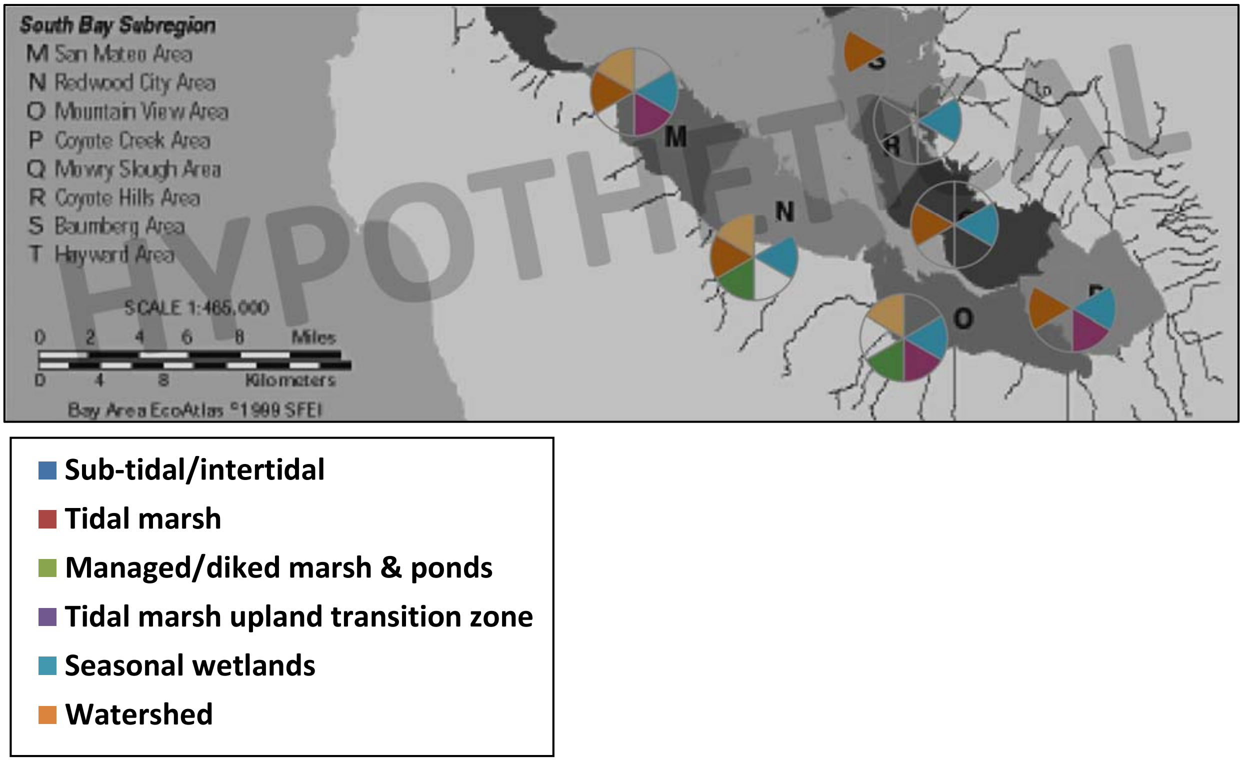


Figure 4.4.2. Illustration of allocating resources by segment and ecosystem.

Hypothetical illustration of how subregional resources could be allocated for conserving ecosystems in each segment (n=8) of the South Bay subregion. Hypothetical allocations are shown as pie charts, where each pie slice represents a percentage of available resources to be allocated toward one of six proposed action categories associated with six respective Bayland ecosystem types. An empty pie slice indicates no resources would be allocated to that particular ecosystem, and in this simplified hypothetical example all ecosystems otherwise receive equal allocations. This allocation method could be applied separately for each management horizon (2015-2029 and 2030-2050). We realized that it would be too onerous to develop an allocation option for all 20 segments by ecosystem in the SF Bay, and so we opted to develop ecosystem-specific allocations at the subregional level instead.

4.5 Making predictions about drivers and conservation outcomes

Here we provide additional explanations for how we made predictions within the subregional decision tools. The approach for making predictions was developed in a way that it could be applied to any ecosystem or subregion in the SF Bay Estuary. Particular emphasis in this section is on how stakeholder input was included in developing the approach. This is a companion to section 3.5.

4.5.1 Developing influence diagrams

Through input from stakeholders during the webinar series, we developed a conceptual model showing linkages between allocation options, external drivers (e.g., extreme storms), and conservation objectives within multiple time horizons (Figure 4.1.1). This relatively simple diagram was useful as a starting point for developing more detailed ecosystem-specific, yet Bayland wide, influence diagrams showing linkages between individual action categories, external drivers, intermediate drivers (e.g., sediment availability), and conservation objectives (Figure 4.5.1).

Each subregional team was provided guidelines for developing a set of ecosystem-specific influence diagrams for the near-term (2015-2029) and long-term (2030-2100) outcome horizons (see Appendix D-1). To ensure the diagrams would remain tractable, teams were asked to include in their diagrams a total of no more than 20 unique factors (not counting the categories of actions). For staying under 20 factors, the guide suggested each ecosystem-specific diagram should contain up to 5 indicators, 3 intermediate drivers, and 3 external drivers for each ecosystem. It was assumed that the external drivers (e.g., extreme storms) would operate at the subregional scale rather than independently for each ecosystem, and so this would help maintain simplicity in the final decision analysis. Teams included only those drivers with the greatest uncertainty in terms of their magnitudes and their relationship to other drivers and effects on the indicators. For example, the rate of sea-level rise during the near-term is quite certain and was therefore not included as an explicit driver within the influence diagrams for the near-term. Instead, sea-level rise in the near-term was considered a constant when making predictions for the outcomes in the near-term.

When designing the breakout guide for developing influence diagrams, the leadership team was aware that there would likely not be numerical models available that would provide the outputs for making the needed predictions for linkages between factors. Instead the anticipation was that an expert elicitation process would be needed to make predictions, and these predictions could be supported by existing information and model results. Limiting the number of included attributes and linkages between them would help ensure that assigning predictions using such an elicitation process would remain feasible. Adding attributes and thresholds leads to an exponentially increasing number of predictions that would need to be made.

The subregional teams referred to the Bayland wide influence diagrams (Figure 4.5.1) as starting points for developing their subregion-specific influence diagrams (henceforth, subregional diagrams). During breakouts at the stakeholder workshop, teams completed a draft influence diagram for each of 3-4 estuarine ecosystems and for each of two outcome horizons. Most of these draft influence diagrams were modified during subsequent meetings following the workshop (Appendix E).

Table 4.5.1. Suggestions and questions from stakeholders about making predictions.

Addressing suggestions and questions raised by stakeholders during the stakeholder webinar series about making predictions about effects of resource allocation options and external drivers (e.g., extreme storms) on conservation objectives in the SF Bay Estuary.

Suggestions

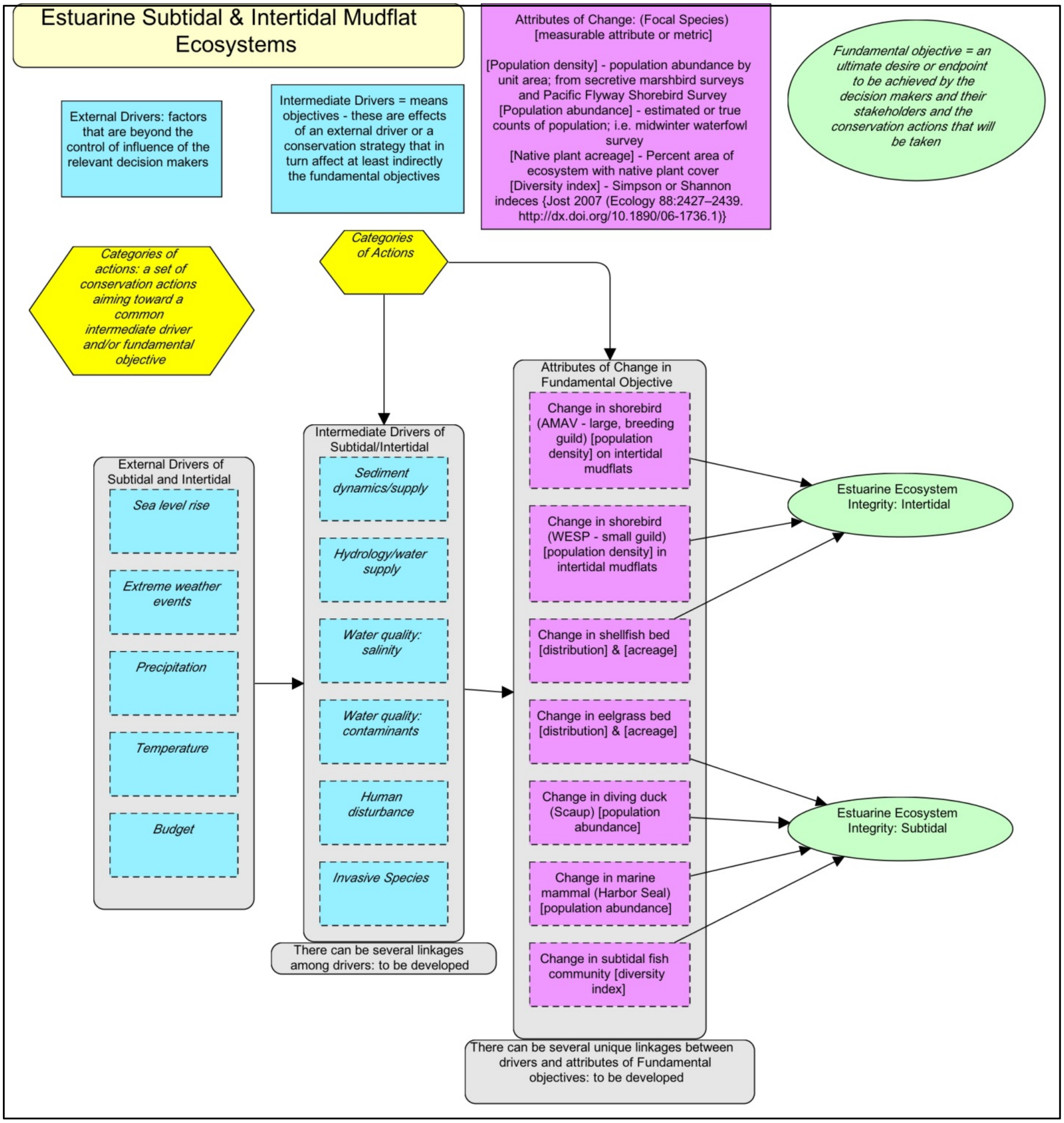
1) *Include sediment dynamics as a critical source of uncertainty (i.e., as an intermediate driver).*
   a. This was adopted for each of the subregions, but in some subregional decision tools this was included implicitly rather than explicitly to maintain the feasibility of the expert elicitation (see section 6.4.2).

Questions

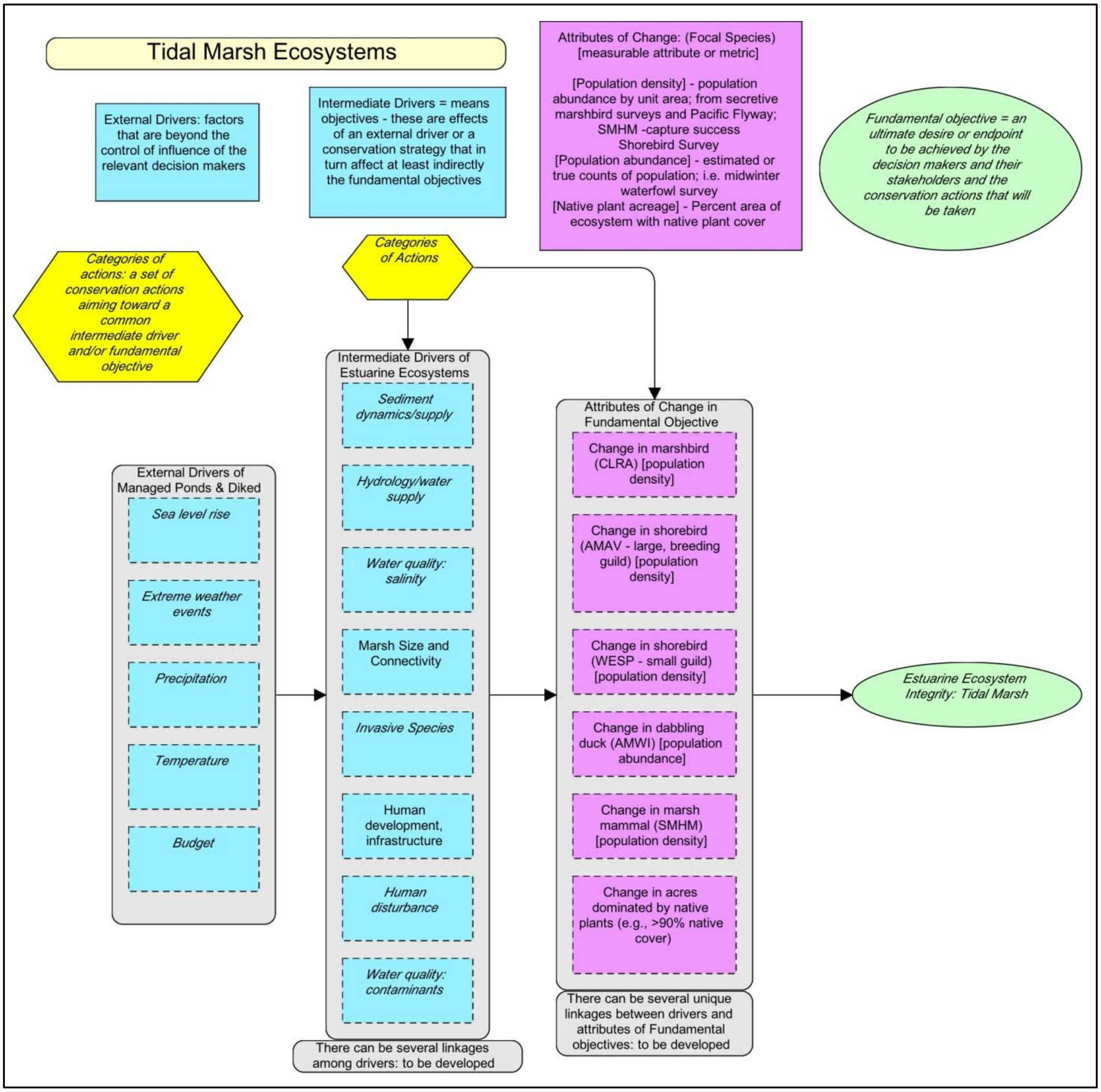
1) *How will existing data and information be assembled to support the predictions within the subregional decision tools?*
   - The leadership lacked capacity to pull together all the relevant pieces of information, but we did encourage subregional teams to refer to available models such as projections for tidal marsh and tidal marsh species through 2100 (Stralberg et al. 2011, Veloz et al 2013).
   - Choosing conservation objectives and linking them back to environmental drivers and action categories via influence diagrams was a huge step forward for informing subregional-scale conservation in SF Bay.
   - The subregional teams kept their decision models simple enough so that the necessary predictions could be populated by experts, and a subsequent decision analysis estimated the expected gain in performance from resolving uncertainty among the experts via further research and modeling. This approach is likely less costly than developing a predictive model for every factor in the decision models.
2) *How will the external drivers and uncertainty will be addressed in the subregional decision models?*
   - We used an expert elicitation process to assign probabilities to the effects of external drivers (e.g., extreme storms) on conservation objectives. By assigning probabilities, we were able to explicitly account for uncertainty about the magnitudes of the external drivers and their effects when arriving at recommended allocations. Accounting for uncertainty in this way also allowed us to make recommendations for future research and monitoring to make more confident decisions.

Figure 4.5.1. Bayland wide influence diagrams by estuarine ecosystem.

Influence diagrams showing coarse linkages between conservation actions and proposed sets of external drivers, intermediate drivers, and indicators for each of the four estuarine ecosystems. Each diagram and the embedded attributes could apply to any subregion in SF Bay. These diagrams were provided at the beginning of the stakeholder workshop and were used as a starting point for developing influence diagrams for each subregion (Appendix E), which formed the basis for the subregional decision tools.

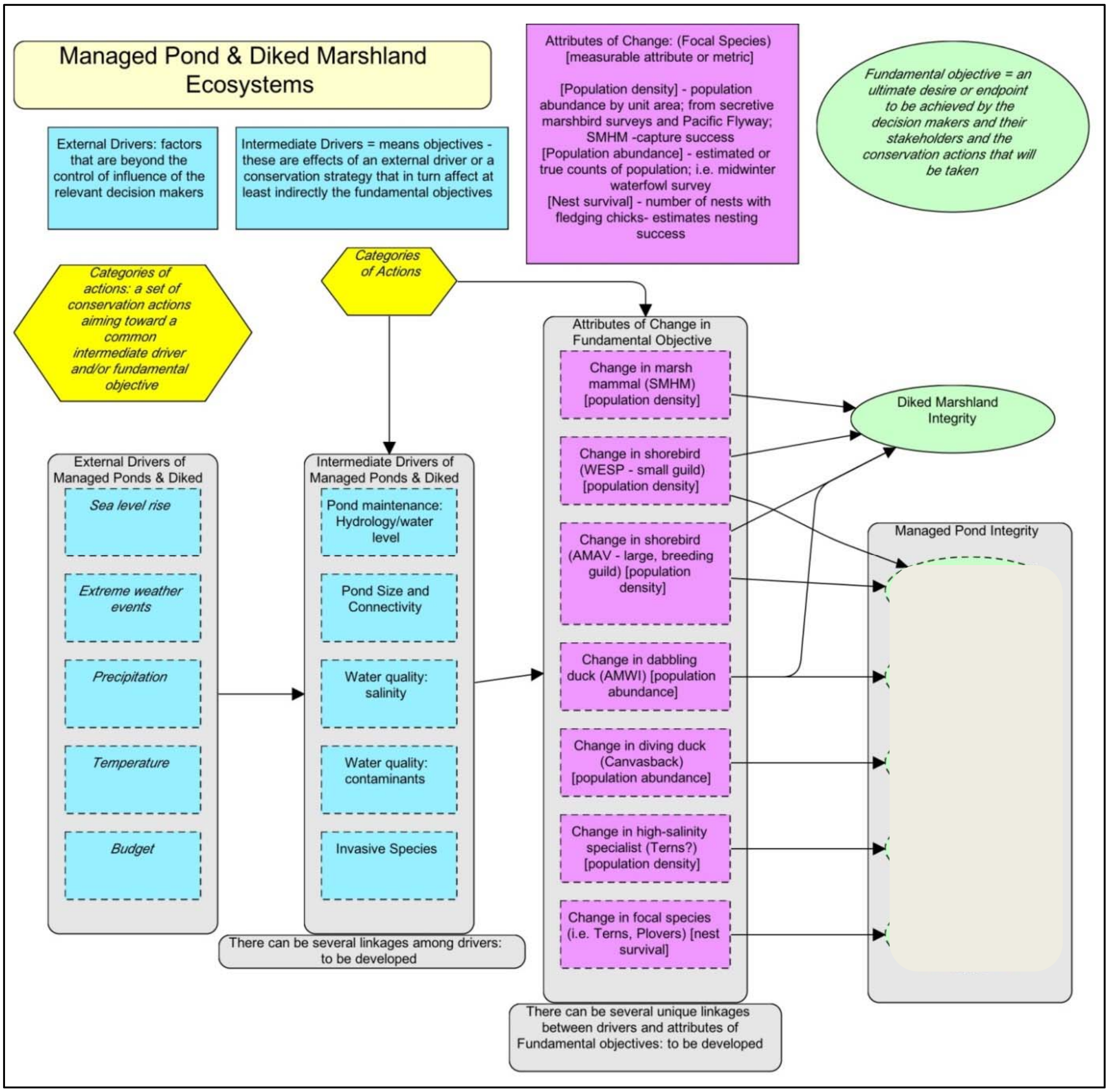


Bayland wide influence diagrams by estuarine ecosystem, continued.



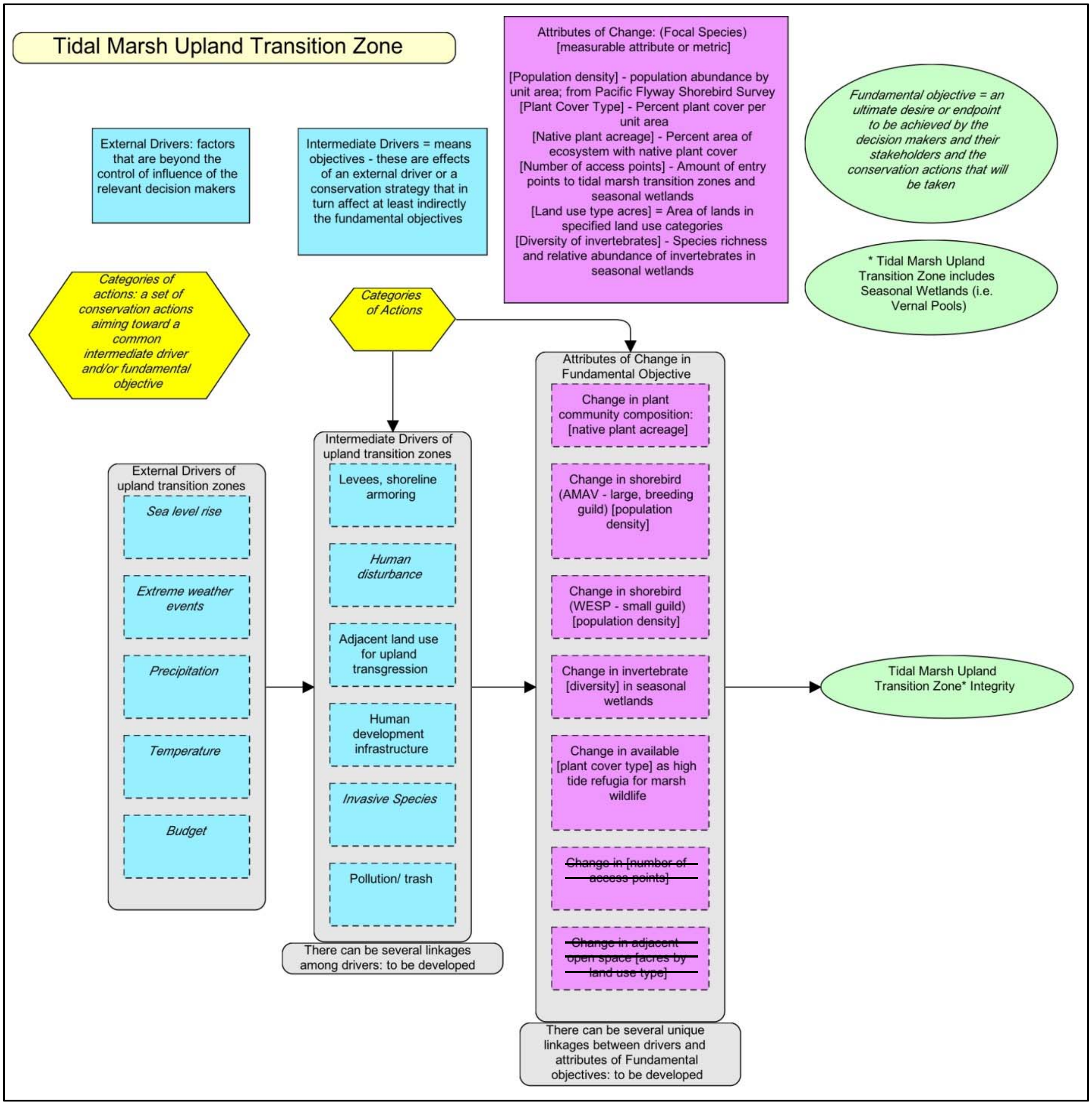
Bayland wide influence diagrams by estuarine ecosystem, continued.

Ignore blank space in "Managed Pond Integrity" box; hidden components were included in error.



Bayland wide influence diagrams by estuarine ecosystem, continued.

Note that two of the attributes for fundamental objectives were included in error and are stricken out in this diagram.



4.5.2 Choosing and defining measurable attributes

Within each subregional diagram, we included a factor representing the change in biotic integrity for that ecosystem during the near-term (2015-2029) and long-term (2030-2100) outcome horizons. This biotic-integrity factor was defined as either **stable/increasing** or **decreasing**, and this was linked to the conditions of the attributes representing biotic integrity for the respective ecosystem (Figure 4.5.2 and section 6.1). For example, in managed wetlands of Suisun, the chosen indicators for the long-term biotic integrity were change in an index of salt marsh harvest mouse abundance and change in wintering duck abundance. Even though the integrity of each indicator of biotic integrity was a desired ultimate outcome of the stakeholders, quantifying tradeoffs among all the indicators for all the focal ecosystems within a subregion would not be feasible.

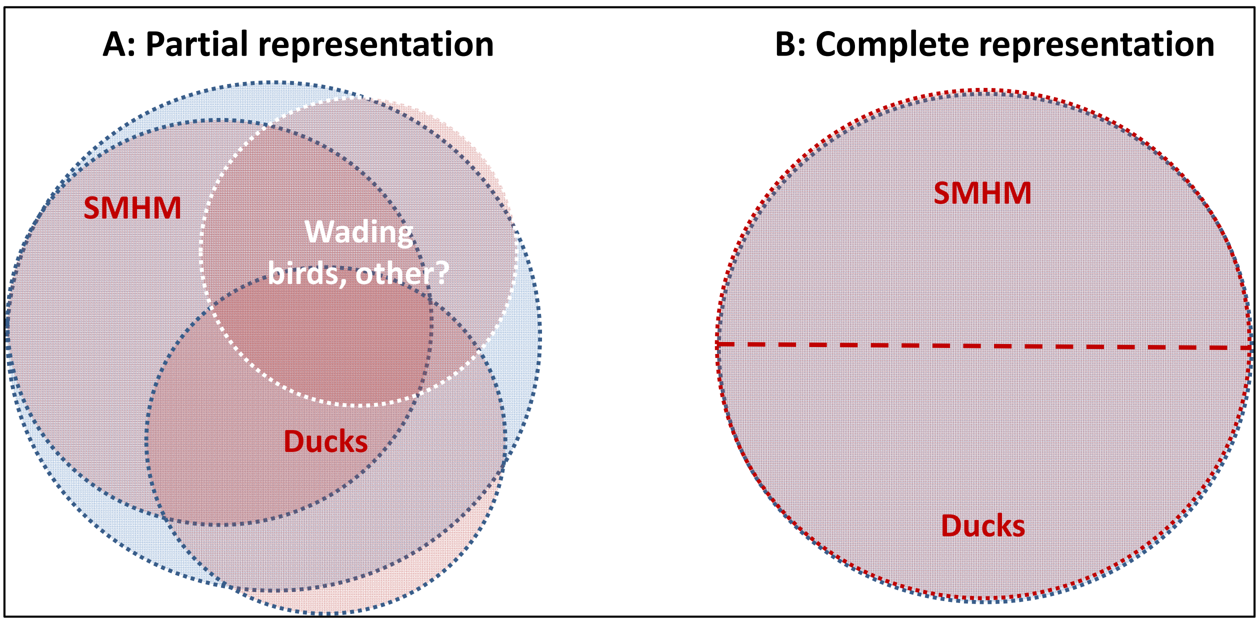


Figure 4.5.2. Example venn diagrams showing indicators of change in biotic integrity.

Venn diagrams showing *hypothetical* levels of overlap between ecosystem attributes (smaller circles) and biotic integrity as a whole (larger circle). The diagram on the left (A) represents a case where the changes in two focal attributes (SMHM = salt marsh harvest mouse abundance, Ducks = winter duck population) represents only a subset of the biotic integrity of managed wetlands in Suisun. Here, changes in the focal attributes would only partially relate to changes in biotic integrity as a whole. Wading birds could represent an additional portion of the ecosystem (e.g., particular trophic level of aquatic invertebrates) that is not represented by the two focal attributes. The diagram on the right (B) represents a case where the two focal attributes together completely represent biotic integrity as a whole, and they represent biotic integrity equally. Here, when both focal attributes are increasing biotic integrity as a whole is decreasing and vice-versa. When one attribute increases and the other decreases then biotic integrity remains constant.

The leadership team began formulating possible indicators (see section 4.2.1) for biotic integrity as preparation for the orientation webinar series, and these proposed attributes were discussed with stakeholders during these webinars. Within a set of Bayland wide influence diagrams, stakeholders were provided with an initial set of indicators along with a set of intermediate and external drivers for each of the four estuarine ecosystems (henceforth, factors) (Figure 4.5.1).

As they developed subregional diagrams, stakeholders added and removed factors and then revised the measurable attributes for each factor in their diagrams. Once the subregional teams were satisfied with a revised set of factors and associated attributes, they were provided guidelines on assigning a threshold value to create two binary levels for each attribute (see Appendix D-1). For each indicator, teams chose two levels (e.g., stable/increasing vs. decreasing numbers of ducks) representing scenarios for where the outcome would be either acceptable (e.g. stable/increasing ducks) or of significant concern (e.g., decreasing ducks) for stakeholders. Subregional teams used the scenarios developed as a larger group when defining the two levels for each external driver (Table 3.4.1 and Table 3.4.2). For intermediate drivers, stakeholders chose a threshold level (e.g., stable water quality) below which there would be significant concerns for the related indicators (e.g. decreasing shorebird abundance). Although having additional levels per attribute (e.g., increasing vs. stable vs. decreasing shorebird abundance) would provide greater resolution in the predictions, this would have required an enormous number of probabilities and would have made the elicitation process infeasible. For a justification for why we elicited probabilities from the stakeholders, see section 3.5.3.

4.5.3 Elicitation process

At the workshop, stakeholders were provided guidelines for the elicitation process, which entailed assigning probabilities to drivers and outcomes for the conservation objectives in the influence diagrams (see Appendix D-4). Before beginning, we discussed a mock example from the Sierra Nevada to illustrate how the probabilities would be determined. During subregional breakouts the stakeholders worked with a decision analyst to fill out probabilities in an Excel spreadsheet, with one spreadsheet tab for each factor in their near-term influence diagrams (there was not enough time to elicit probabilities for the long-term factors during the workshop). Each stakeholder entered their probabilities independent of the other team members to avoid possible bias. All but one of the subregional teams completed a round of elicitation for the near-term factors in each of their ecosystem-specific influence diagrams during the workshop.

Following the workshop, the leadership team developed a more detailed set of guidelines for completing the elicitation process (Appendix G). The most important guidelines are summarized here. For factors that were driven directly by the resource allocation, the resource-availability scenario (e.g. “Rosy”; Table 3.4.2) and the percentages allocated to action categories relevant to that factor would need to be carefully considered. Action categories linked to a given factor were shown on the influence diagram (see section 3.5.1) for the estuarine ecosystem where the factor originated. In addition to the resources being applied for a particular factor, there were often one or more environmental drivers to be considered when assigning a probability of an outcome. Therefore, stakeholders needed to refer to the allocation options and influence diagrams while filling out their probabilities. Stakeholders were encouraged to refer to any and all information (e.g., Stralberg et al.

2011, Veloz et al 2013) and their own experience when assigning probabilities. Finally, stakeholders assigned a probability that biotic integrity would be stable or increasing as a function of the indicators they chose to represent biotic integrity (Figure 4.5.2). Probabilities for stable/increasing biotic integrity, therefore, were higher when the attributes were in good condition and if the stakeholder believed that the attributes well represented the biotic integrity as a whole. By contrast, these probabilities were lower if the stakeholder believed the attributes only partly or poorly represented biotic integrity as a whole. In addition to the enhanced guidelines, a question was written out for each attribute so that the stakeholders could better understand what was being asked when assigning their probabilities. Below this question in the spreadsheet, stakeholders were asked to provide a probability for each of the possible combinations of the related factors (Table 4.5.2).

Table 4.5.2. Example table for eliciting probabilities.

Example table showing method for eliciting probabilities of stable/increasing diving duck populations during the near-term (2015-2029) in South Bay. Shaded cells indicate pessimistic scenarios for the drivers of diving duck populations. For near-term allocation options see Table 5.4.5, and for resource availability scenarios see Table 3.4.2.

Question for stakeholder: From your perspective, what is the likelihood (0-100) that the diving duck populations in managed ponds will be stable/increasing over the near-term (2015-2029), as a function of near-term water quality (Suitable vs. Unsuitable for bird food), Allocation Option, AND Resource Availability?

Probability of stable or increasing diving duck population	Water quality	Allocation option	Resources
	Suitable	Assume Rosy	Rosy
	Suitable	Assume Rosy	Not so good
	Suitable	Assume Not So Good	Rosy
	Suitable	Assume Not So Good	Not so good
	Unsuitable	Assume Rosy	Rosy
	Unsuitable	Assume Rosy	Not so good
	Unsuitable	Assume Not So Good	Rosy
	Unsuitable	Assume Not So Good	Not so good

Completing the elicitation process involved a series of steps. First, each stakeholder completed their spreadsheet and submitted it to the decision analyst. Within each spreadsheet, the decision analyst checked for logical consistency among elicited probabilities for factors with more than two elicited probabilities (i.e., at least one driver as in Table 4.5.2). For example, the likelihood that diving ducks are stable/increasing when water quality is suitable must be at least as likely as when water quality is unsuitable. The decision analyst resolved logical inconsistencies with stakeholders individually. Then outliers (i.e., probabilities >20% away from the nearest probability) were identified for each elicited probability, and the decision analyst asked stakeholders individually to either provide a justification or adjust their probability after considering the other inputs given. For Central Bay, this step was not possible due to time constraints. Finally, the decision analyst calculated summaries (i.e., averages, minimums, and maximums) across stakeholders for each elicited probability in the final set of spreadsheets for use in the sensitivity analysis (see section 3.7.2).

4.6 Identifying & quantifying tradeoffs

This is a companion to section 3.6.

Table 4.6.1. Suggestions and questions from stakeholders about tradeoffs.

Addressing suggestions and questions raised by stakeholders during the stakeholder webinar series about tradeoffs among conservation objectives in the SF Bay Estuary.

Suggestions

1) *Account for tradeoffs between near-term and long-term outcomes.*
    - This was adopted
2) *Include tradeoffs between sediment-management objectives (i.e., conserving native aquatic species in the estuary) and watershed management objectives (e.g., conserving native upland species).*
    - We ended up focusing on tradeoffs among ecosystem-specific changes in biotic integrity within the SF Bay Estuary rather than tradeoffs in the watershed.
    - Subregional teams, however, were aware of this tradeoff when developing their allocation options, which included allocations to the watershed ecosystem. We considered effects of sediment management on upland species as imposing a constraint on actions that could be taken in the uplands.

Questions

1) Will costs of actions will be considered, and how will these costs be traded off with the conservation objectives?
    - We arrived at a decision question (Table 4.1.4) that focused on identifying recommended resource allocations under uncertainties including future resource availability. The costs of actions need to be considered when developing options for allocating among action categories (see section 3.4), as some action categories are likely more expensive than others but would be expected to have a more positive influence as more resources are allocated to them. Although stakeholders were not asked to explicitly evaluate tradeoffs between costs and conservation outcomes, these tradeoffs were an implicit part of the recommendation.

4.7 Identifying recommended allocations

During the webinar series we discussed a hypothetical approach to identifying a recommended , allocation (Figure 4.7.1), which was later modified in two ways. First, the hypothetical approach proposed that an optimal combination of allocation options among subregions could be sought. Through further discussions with stakeholders, we chose to instead identify a recommended allocation for each subregion separately to better reflect the way decisions are made in the Baylands. Second, the hypothetical approach did not distinguish two separate management horizons. For the subregional decision tools, we did consider both a near-term (2015-2029) and a longer-term (2030-2050) management horizon to allow for adapting the allocation to new information and anticipated changes in the ecosystems themselves during the near-term.

Table 4.7.1. Questions and concerns from stakeholders about approach to making recommendations.

Addressing questions raised by stakeholders during the stakeholder webinar series about making subregional recommendations for conservation in the SF Bay Estuary.

Questions

1) *How would a score be determined for comparing the performance of allocation options?*
    - Scores for the allocation options in the hypothetical example were simulated to demonstrate potential differences in expected performance of the conservation objectives among allocation options. Each score represents 1) how stakeholders tradeoff multiple conservation objectives (see section 3.6), and 2) uncertainty about the outcomes of the conservation objectives (see section 3.5.3).
    - The best possible allocation would have a score of 100, and the worst would have a score of 0.
2) *Would the score be based on goals and objectives from existing conservation plans?*
    - Scores of expected performance will reflect previously identified conservation objectives along with additional objectives and modifications to existing objectives through discussions with stakeholders (see section 3.7).

Concerns

1) *Concerned that the CADS process could be used to make financial decisions in an era of limited resources based on a model with such a high degree of uncertainty and lack of thoughtfully considered scientific input.*
    - Unlike any other before the CADS project involves a transparent process for writing out linkages between action categories, external drivers, and measurable conservation objectives, along with specifying uncertainties in the form of probabilities that are elicited independently from each stakeholder. Together, these ingredients allow for examining which uncertainties (if any) can influence the recommended allocation option. That way, many of the model assumptions can be addressed through a sensitivity analysis to evaluate the robustness of the recommended allocations and to reveal uncertainties that are worth resolving through future research and analysis.
    - Although more resources (beyond what was committed for CADS, BEHGU, and other Bayland wide efforts) could be invested in research and planning for conservation of the SF Bay Estuary, we saw it worthwhile to develop recommended allocations through the CADS process seeing as how resources will otherwise be allocated in a more ad hoc way that does not integrate the inputs from stakeholders like we have done. Furthermore, the CADS process was meant to reveal the crucial areas to focus on for further research that could improve conservation in the Estuary.

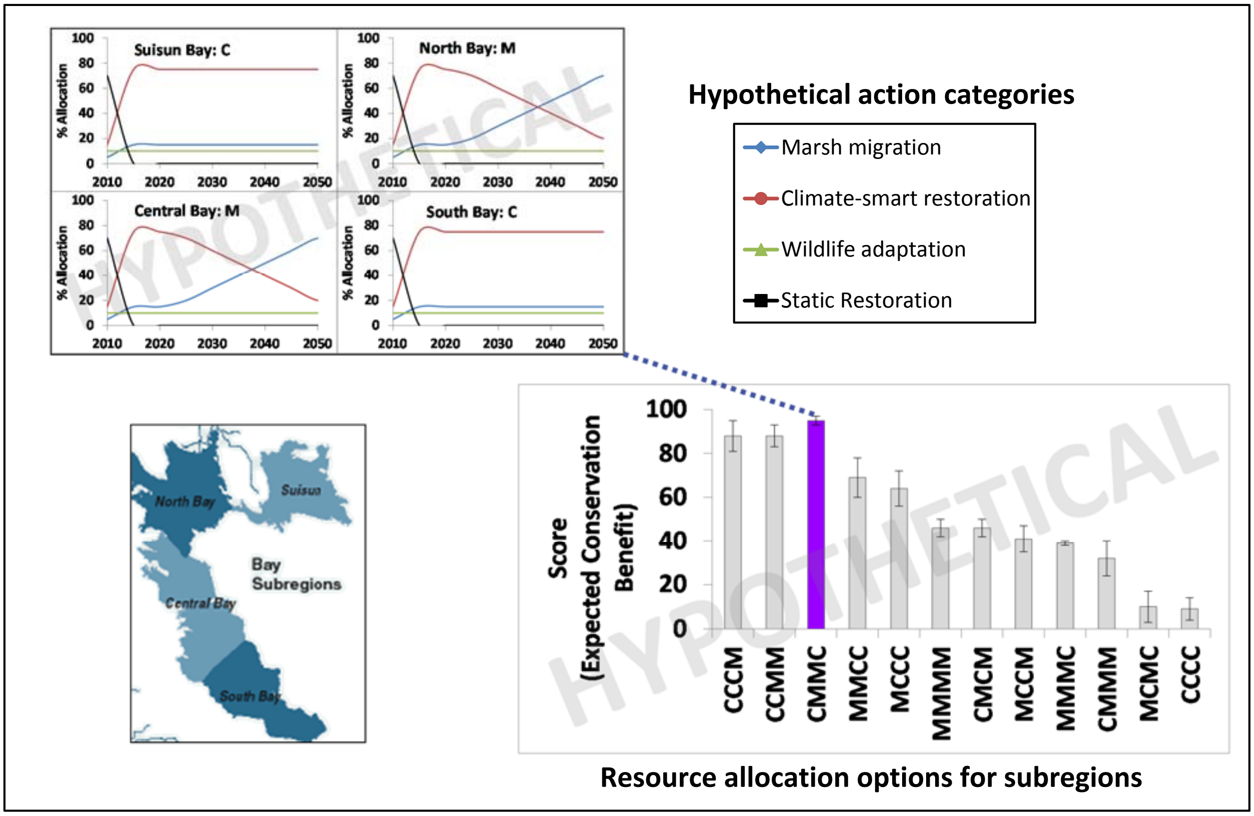


Figure 4.7.1. Hypothetical approach for making subregional management recommendations.

Hypothetical illustration of an approach to identify recommended allocation options within each of the four subregions of SF Bay, as presented during the second orientation webinar. The hypothetical temporal allocation graphs for each subregion (shown in upper left) were adapted from those developed for conserving tidal marshes of SF Bay (Thorne et al 2015). The hypothetical action categories in the allocation graphs were taken from Thorne et al. (2015) and had not been discussed or formulated yet for CADS. In this hypothetical example, a temporal allocation option would be developed for each subregion and then assigned a letter code corresponding to the action category with the highest allocation. For Suisun Bay and South Bay the dominant action category is climate-smart restoration, and so the letter C is assigned to these hypothetical subregion-specific allocations. In contrast, North Bay and Central Bay are assigned an M because the marsh migration action category is dominant. A letter code of CMMC represents this combination of allocations. A decision-analytic tool would be used to quantify and compare expected performance scores (in terms of conservation objectives) among allocation alternatives (hypothetical scores shown in graph on lower right). These hypothetical action categories and allocation options were replaced following the webinar, and the approach to identifying recommended allocations was refined.

Chapter 5. Subregional decision tools and management recommendations

This chapter provides recommendations for subregion-specific resource allocations to conserve the SF Bay Estuary in the near-term (2015-2029) and in the long-term (2030-2100). As such, it is geared toward decision-makers and stakeholders focused on conservation within one or more of the four SF Bay subregions. Each recommendation is based on a subregion-specific decision tool that was refined following the stakeholder workshop. Chapter 3 summarizes the process and intermediate products needed to generate draft subregional decision tools at the stakeholder workshop in May 2014, and this earlier chapter is referenced often within the current chapter for those who want to gain a better understanding of the foundations for the subregional decision tools. The draft subregional decision tools (from the workshop) were used as starting points for refinement and for eventually arriving at resource allocation recommendations in each subregion.

Subregional decision tools were refined after the stakeholder workshop using nearly the same sequence as for developing the draft versions through the end of the workshop (see Chapter 3).

1) Refining decision frame and project design (not adjusted by subregional teams))
2) Engaging stakeholders and experts
3) Refining conservation objectives
4) Refining action categories
5) Developing resource allocation options
6) Making predictions
7) Identifying recommended allocations and main findings
8) Comparison of subregional decision tools and recommendations

Step 1 was not needed, as the stakeholders adopted the decision frame as discussed during the stakeholder workshop (see section 3.1). Subregional decision tools were refined from June 2014 through January 2015 via monthly webinars, emails, and individual calls with a decision analyst and stakeholders focused on each of the four subregions (Table 2.2.3). South Bay and North Bay teams both completed their adaptive decision tools, which provided recommendations for resource allocations during the near-term (2015-2029) and longer-term (2030-2100) management horizons. Suisun and Central Bay both completed a decision tool that provided a recommended resource allocation for the near-term management horizon. Successes and challenges of developing the products in the funded proposal are further discussed in Chapter 6.

5.1 North Bay

The subregional teams adopted a general decision frame at the beginning of the stakeholder workshop (see section 3.1) that was used to develop and refine their subregional decision models. The decision question for the North Bay team, then, was:

How should resources be allocated across ecosystem types and categories of actions in the North Bay to achieve ecosystem integrity objectives for the North Bay estuarine ecosystems?

The subsections below provide a description of how this decision question was addressed, culminating with recommended North Bay resource allocations for a near-term (2015-2029) and a longer-term (2030-2050) management horizon.

5.1.1 Engaging stakeholders and experts

Stakeholders who participated in refining the North Bay decision model following the workshop were the same the group who worked together in the workshop breakout sessions (Table 2.2.3), with the exception of two individuals who were not able to devote more time to the project. There were also two additional experts that were unable to attend the workshop but who provided much-needed expertise for some ecosystems within the North Bay during the subsequent analysis for the decision framework. The post-workshop team (composed of a decision analyst and 4-6 stakeholders) discussed model revisions and results during five conference calls. The decision analyst also communicated with the stakeholders individually via emails and an occasional phone call.

5.1.2 Refining conservation objectives

The North Bay team adopted the estuarine ecosystem classification that was discussed as a larger group at the workshop: subtidal and intertidal mudflats, tidal marsh, managed ponds and diked marshes, and upland transition zone (Table 3.1.2). For each ecosystem, the team defined an overarching fundamental objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) and long-term (2030-2100) outcome horizons in North Bay. At the start of the workshop, stakeholders were provided a list of proposed indicators of biotic integrity that could apply to each of these ecosystems anywhere in the SF Bay Estuary (Table 3.2.2). Starting from this set, the team developed a revised set of 16 indicators of biotic integrity in each ecosystem (Table 5.1.1). Indicators, each of which were measurable and represented a unique aspect of the ecosystem, were also chosen to represent the most important desired outcomes for stakeholders.

Table 5.1.1. Indicators of biotic integrity for estuarine ecosystems of North Bay.

Final set of 16 indicators to represent stable or increasing biotic integrity as an ultimate desired outcome in each of four estuarine ecosystems in North Bay. Each indicator was classified as stable or increasing vs. decreasing during each outcome horizon. Unless otherwise noted, each indicator was used for both the near-term (2015-2029) and long-term (2030-2100) outcome horizons.

Subtidal & intertidal mudflats

1) Shorebird diversity and abundance
2) Shellfish bed acreage
3) Eelgrass bed acreage
4) Forage for diving duck populations
5) Salmonid abundance (representing subtidal fish community)

Tidal marsh

6) Ridgway's Rail (representing marshbird) density
7) Salt marsh harvest mouse (representing small mammal) density
8) Native fish diversity and abundance
9) Acreage dominated by native plants

Managed wetlands[a]

10) Fish abundance
    a. Abundance of natives for near-term
    b. Density of natives per wetland structure for long-term
11) Shorebird richness and density
    a. Total richness and density for near-term
    b. Average richness and density per wetland structure for long-term
12) Duck richness and density

Upland transition zone

13) Acres dominated by native plants
14) Density of Song Sparrows and Common Yellow Throats
15) Acres with vegetated refugia available at king tide (represents important habitat for salt marsh harvest mouse and Ridgway's Rail)
16) Herpetofauna abundance

[a] Many managed wetland structures will not be maintained throughout the long term, and so indicators of biotic integrity here are summarized "per structure" to focus on those structures that will be maintained in the future.

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5.1.3 Refining action categories

The North Bay team used the action categories defined for the workshop as a whole (Table 3.3.1), with the exception of combining the “manage water quality” and “manage water quantity” categories into a single “manage water” category as did other subregions (see section 6.2). They assumed that the actions taken within a category would be similar to those defined in the BEHGU recommendations for North Bay (Table 5.1.2), as well as other actions that the North Bay team believed would be feasible and necessary in the region (e.g., the “manage individual wildlife species” action category consisted of strategies such as captive breeding, assisted migration, floating islands, and oyster restoration).

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Table 5.1.2. Recommended actions from BEHGU for North Bay.

	SF Bay CADS Action categories						SF Bay CADS Bayland ecosystems					
BEHGU recommended actions	Protect acreage	Manage sediment	Manage wildlife species	Manage vegetation	Manage water	Manage human disturbance	Subtidal & intertidal	Tidal marsh	Managed wetlands	Upland transition zone	Migration Space	Water-shed
Protect uplands adjacent to baylands by the use of easements, fee titles, etc.	X						X	X	X	X	X	X
Restoration of diked baylands and salt ponds in the Napa-Sonoma Marsh should occur as soon as possible to maximize sediment accretion ahead of expected regional suspended sediment decline and rapid acceleration in sea-level rise.	X	X			X				X			
Riparian woodland and floodplain grassland vegetation corridors should be restored between tidal baylands and lower watersheds, for the benefit of wildlife and plant populations linked to transition zones, and for ecosystem services related to nutrient transformation, groundwater and sediment delivery.	X	X		X								X
Fringing high marsh bordering northern San Pablo Bay should be managed to sustain extensive high salt marsh by minimizing artificial drainage obstructions and maximizing wave processes to deposit coarser sediment as sea level rises.		X						X				
Implement Early Detection Rapid Response and control of non-native exotic species			X	X			X	X	X	X		
Shallow subtidal submerged aquatic vegetation beds (including eelgrass beds in the southern extent of this subregion) should be preserved and augmented, where new opportunities arise as turbidity declines				X			X					
Low-turbidity interior tidal pond habitats suitable for other native submerged aquatic vegetation types (Ruppia, pondweed beds) should be incorporated in tidal marsh restoration along salinity gradients of major tributary creeks and rivers				X				X				X
Reduce pollution from agricultural lands by tying into non-point source pollution control					X	X					X	X
Transportation infrastructure (roads such as Highway 37 and rail lines) that obstruct water and sediment processes and wildlife connectivity should be adapted to sea level rise in a manner that improves ecosystem resilience, e.g., gradients to accommodate change.						X					X	
Prevent new infrastructure along shoreline and stop planting vineyards in areas in low gradient areas that will be subjected to high salinities in the future.						X					X	
In upstream areas, prevent and remove barriers to stream flow and eliminate or remove any permitted or unpermitted drawing of water (i.e. to irrigate vineyards)						X						X

5.1.4 Developing resource allocation options

The North Bay team adopted the external driver scenarios developed during the workshop plenary (Table 3.4.1 and Table 3.4.2) and used this information to develop a pair of allocation options for the near-term (2015-2029) (Table 5.1.4 and Figure 5.1.1) and another pair of allocation options for the longer-term (2030-2050) (Table 5.1.5 and Figure 5.1.2) management horizon to best achieve the conservation objectives (see section 5.1.2 above) for North Bay from 2015-2100. In the long-term horizon (2030-2100), sea level is expected to rise at a faster and more uncertain rate compared to the near-term horizon. Stakeholders took this into account when assigning allocation percentages.

There were essentially two steps for developing each allocation option. First, the team assigned a subjective score between 0 and 100 to each action-category-ecosystem combination, representing a qualitative ordering of how much would be allocated to each action category and the ecosystem where it would be implemented. The team then rescaled these scores so that the total of the allocations equaled 100 and each value represented a percentage of total resources available. The team considered how (to which action category) and where (in which ecosystem) resources should be allocated to conserve biotic integrity of the estuary under a given scenario for the future (Table 5.1.3).

Table 5.1.3. Justifications for resource allocations in North Bay.

Justifications for percentages under two allocation options in a near-term (2015-2029) and two allocation options in a longer-term (2030-2050) management horizon within North Bay. One option assumes the future (2015-2100) will be 'rosy' for future resource availability and external environmental drivers, and the other option assumes the long-term future will be 'not-so-great'. For allocation options see Table 5.1.4 and Table 5.1.5; for full description of future scenarios see Table 3.4.1 and Table 3.4.2).

	Near Term (2015-2029)		Medium Term (2030-2050)	
Action category	**Rosy**	**Not So Great**	**Rosy**	**Not So Great**
Protect acreage	Subtidal acreage is already protected. Took into account recommendations for living shoreline reef construction for managing sediment.	The allocations are for renegotiating leases for state lands	Opportunities to protect existing tidal marsh will decrease, so there is a need to allow for it to re-establish, and allow for more migration space work. Continuing to look for willing sellers for transition zone and migration space.	
Manage sediment		It's less expensive to manage subtidal sediments because things like pipelines aren't necessary, so this can be done even with poor resource availability.		
Manage wildlife species			Managing for individual species is difficult to do and might not be a good use of resources except in extreme cases. However, there probably will be more wildlife management in the future	
Manage vegetation			Vegetation work will not be as intensive in the long term. Some subtidal projects have plans for offshore eelgrass restoration.	
Manage water quality	Allocation for water management was less than in the diked historic baylands because these structures take up a smaller proportion of the transition zone landscape			
Manage disturbance		It's difficult to access the subtidal habitat, so very little was allocated for disturbance in this ecosystem	Human disturbance might be greatest in the tidal marsh and UTZ, especially at high tide because that's where the animals will be going	Might be that the easiest, most cost effective thing to do is deal with access issues through human disturbance. The less space there is, the more you have to guard it

Table 5.1.4. Near-term resource allocation options for North Bay.

Allocation options for a near-term (2015-2029) management horizon to conserve estuarine ecosystems in North Bay from 2015-2100. Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics, resource availability) from 2015-2100 and resource availability in the near-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of six Bayland ecosystems. Darker shaded cells have a higher percentage allocation.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh	Diked baylands and managed ponds	Upland transition zone	Migration Space	Watershed	TOTAL
Assume Rosy Future							
Protect acreage	1	2	13	13	13	0	*42*
Manage sediment	2	2	10	5	5	0	*24*
Manage individual wildlife species	1	2	1	2	0	0	*6*
Manage vegetation for multiple species	1	2	2	4	6	0	*15*
Manage water	0	0	2	1	1	0	*4*
Manage human disturbance	2	2	2	2	1	0	*9*
TOTAL	*7*	*10*	*30*	*27*	*26*	*0*	*100*
Assume Not-So-Great Future							
Protect acreage	1	3	10	10	10	0	*34*
Manage sediment	2	2	4	2	1	0	*11*
Manage individual wildlife species	2	6	6	9	1	0	*24*
Manage vegetation for multiple species	1	4	4	6	1	0	*16*
Manage water	0	0	3	1	1	0	*5*
Manage human disturbance	1	2	2	2	3	0	*10*
TOTAL	*7*	*17*	*29*	*30*	*17*	*0*	*100*

Table 5.1.5. Longer-term resource allocation options for North Bay.

Allocation options for a longer-term (2030-2050) management horizon to conserve estuarine ecosystems in North Bay over the long-term (2030-2100). Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics, resource availability) and resource availability in the longer-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of six Bayland ecosystems. Darker shaded cells have a higher percentage allocation.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh	Diked baylands and managed ponds	Upland transition zone	Migration Space	Watershed	TOTAL
Assume Rosy Future							
Protect acreage	1	1	7	9	9	0	*27*
Manage sediment	5	0	13	6	5	0	*29*
Manage individual wildlife species	1	3	1	3	0	0	*8*
Manage vegetation for multiple species	1	2	2	4	3	0	*12*
Manage water	0	1	2	0	0	0	*3*
Manage human disturbance	3	5	3	5	5	0	*21*
TOTAL	*11*	*12*	*28*	*27*	*22*	*0*	*100*
Assume Not-So-Great Future							
Protect acreage	1	3	4	12	15	0	*35*
Manage sediment	0	2	4	3	1	0	*10*
Manage individual wildlife species	1	8	6	8	0	0	*23*
Manage vegetation for multiple species	0	1	1	6	6	0	*14*
Manage water	0	0	3	1	1	0	*5*
Manage human disturbance	0	2	2	4	4	0	*12*
TOTAL	*2*	*16*	*21*	*34*	*27*	*0*	*100*

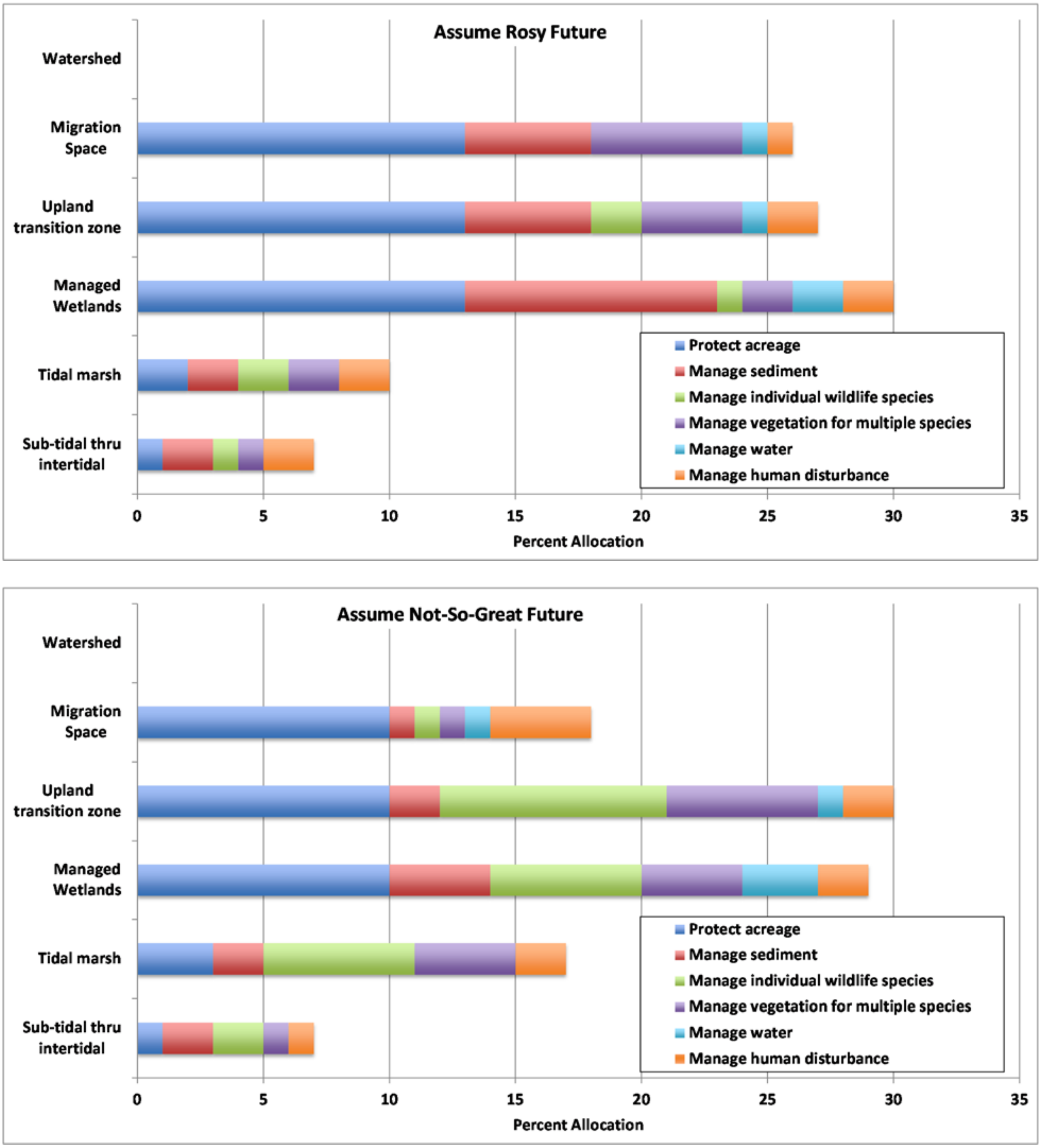
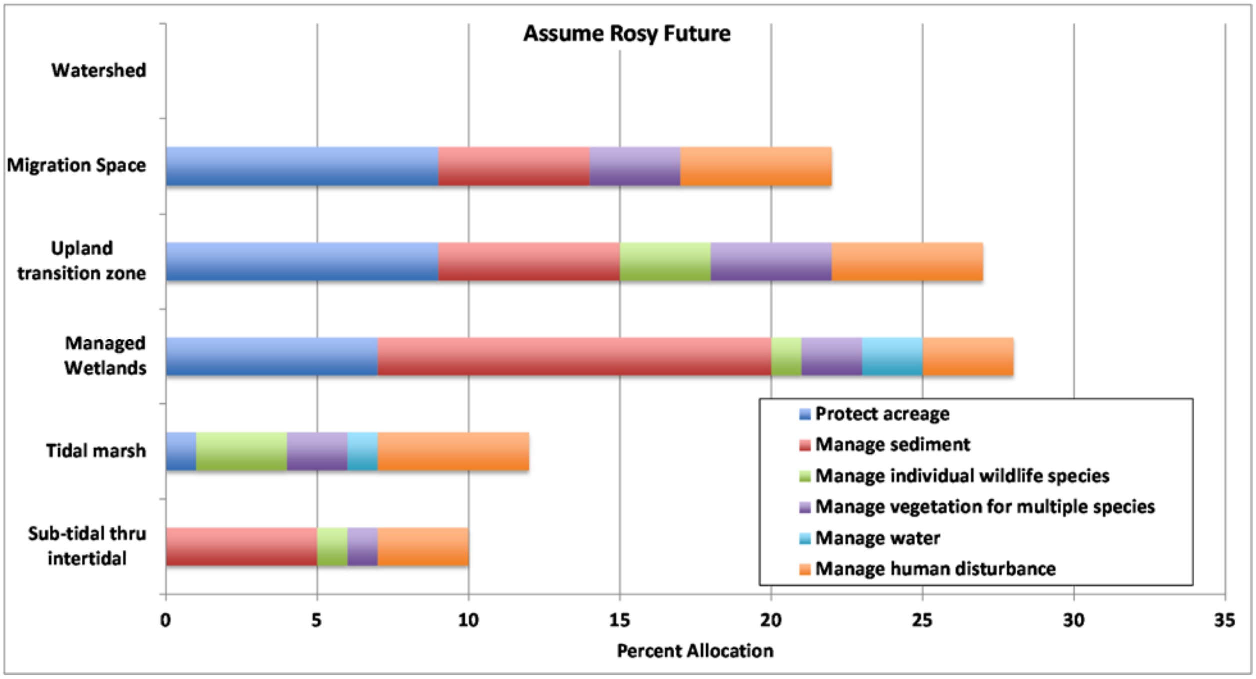


Figure 5.1.1. Near-term allocation options for North Bay.

Percent allocations to action categories (color codes in legend) within each of 6 Bayland ecosystems (y-axis) during the near-term (2015-2029), under two alternate future scenarios (2015-2100) for North Bay. See Table 3.4.1 and Table 3.4.2 for descriptions of the future scenarios.



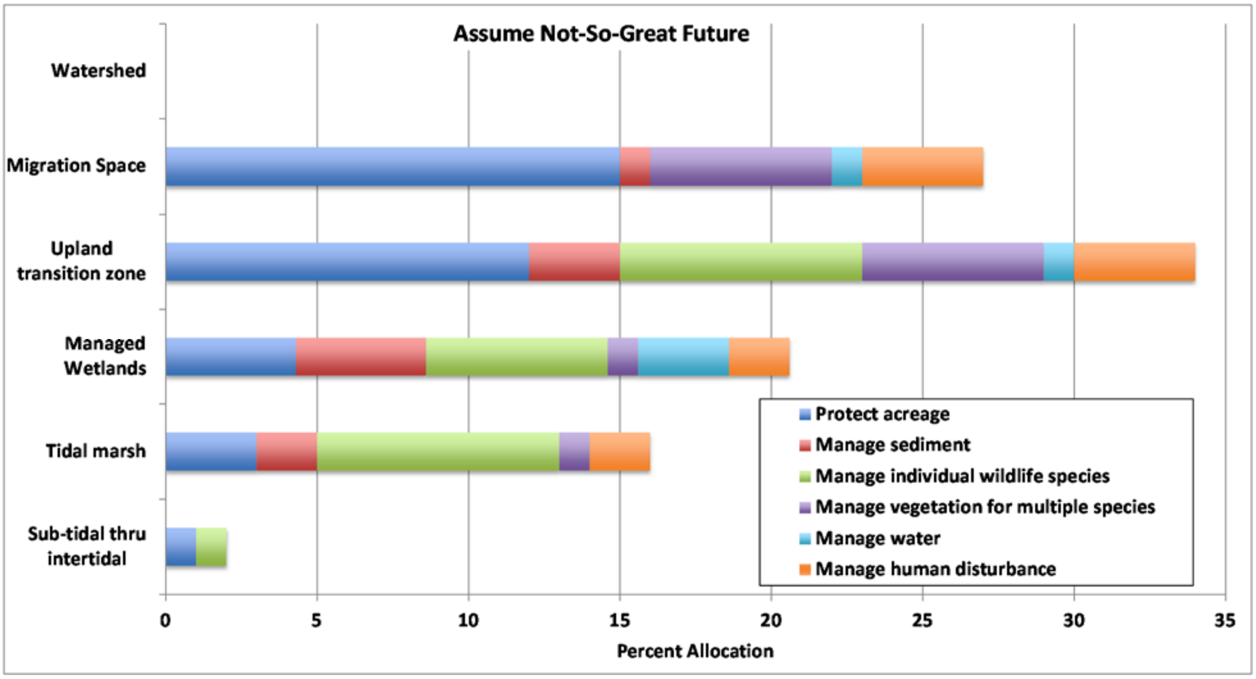


Figure 5.1.2. Longer-term allocation options for North Bay.

Percent allocations to action categories (color codes in legend) within each of 6 Bayland ecosystems (y-axis) during the longer-term (2030-2050) management horizon, under two alternate future scenarios (2030-2100) for North Bay. See Table 3.4.1 and Table 3.4.2 for descriptions of the future scenarios.

5.1.5 Making predictions about drivers and conservation outcomes

In the workshop breakout sessions, the North Bay team began carrying out 3 of the following 4 steps:

1) (Provided in plenary: Ecosystem-specific influence diagrams linking action categories and external drivers (e.g., extreme storms) to the conservation objectives, which could apply to any subregion.)

2) Refine ecosystem-specific influence diagram for the focal subregion showing how the conservation objectives are related to indicators, and in turn how indicators are affected by action categories and external drivers via intermediate drivers.

3) Choose measurable attributes and binary levels (e.g., stable/increasing vs. decreasing) for the indicators, intermediate drivers, and external drivers within the influence diagrams.

4) Assign probabilities to possible outcomes for the conservation objectives and how they are related to indicators, and in turn how indicators are related to external drivers and resource allocation, sometimes via intermediate drivers.

Step 1 was already completed and diagrams provided to stakeholders before the breakout sessions. The North Bay team carried out steps 2-4 in an iterative fashion starting during the workshop breakouts and completed through the subregional team meetings during and after the stakeholder workshop (see section 5.1.1).

Following a set of guidelines during workshop breakouts (see section 3.5.1), the North Bay team developed an influence diagram for each of the four estuarine ecosystems in the near-term and in the long-term (Appendix E-1), which were modified from influence diagrams provided during plenary (Figure 4.5.1). Each ecosystem-specific influence diagram showed linkages between indicators representing biotic integrity (overarching conservation objective), intermediate drivers, external drivers (i.e., beyond the control of North Bay conservation partners), and categories of actions (Table 3.3.1).

5.1.5.1 External drivers and intermediate drivers

Attributes and thresholds between binary levels for the indicators of biotic integrity in North Bay were described in section 5.1.2. Here we describe the attributes and thresholds for each intermediate driver and each external driver that are linked directly or indirectly to the indicators in the influence diagrams (Appendix E-1).

External drivers affect estuarine ecosystems and are beyond the control of managers. The North Bay team adopted future scenarios for external environmental drivers as discussed in plenary (Table 3.4.1), and from these four external environmental drivers were identified for North Bay (Table 5.1.6). The team adopted the Rosy and Not-So-Great scenarios developed during plenary for resource availability (Table 3.4.2), and this was included as an external driver.

Intermediate drivers influence indicators and are themselves influenced by external drivers and/or actions. Team members recognized there are many intermediate drivers that could be included, but to ensure a concise decision model they limited the influence diagrams to the drivers having the greatest uncertainty and greatest potential impacts on the fundamental objectives. Additionally, although these intermediate drivers were included in the influence diagrams, they were not explicitly included in the final decision model. Rather, the team was asked to consider these drivers while providing their predictions of how the action categories and external drivers influence the indicators (see section 5.1.5.2).

Table 5.1.6. External drivers for the North Bay decision tool.

For the North Bay decision tool, three external drivers were included for the near-term (2015-2029) and three for the long-term (2030-2100) outcome horizon. Unless otherwise noted, these were classified to be consistent with the scenarios discussed during the workshop plenary (Table 3.4.1).

1) *Sea level rise (SLR) effect (near-term only)*
   - SLR effect reflects the great deal of uncertainty about how the tidal marsh ecosystem will be affected by even a small and predictable amount of SLR in the near-term.
2) *Sea level rise (long-term only)*
   - "Not-So-Great" SLR is 165 cm greater than 2014 level. "Rosy" SLR is 52 cm greater than 2014 level.
3) *Extreme weather events*
   - Frequency and intensity of drought and storms, along with accompanying king tides.
4) *Temperature and precipitation patterns*
   - “Normal” is defined as the slow upward trend we are seeing now in temperature and following the current long term trend for precipitation patterns. “Abnormal” is a deviation from “Normal”.

Table 5.1.7. Intermediate drivers by ecosystem for North Bay.

These intermediate drivers were included implicitly rather than explicitly in the North Bay decision tool, to support the predicted effects of external drivers and action categories on indicators of biotic integrity while keeping the tool tractable. The intermediate drivers are defined in Appendix F .

	Near-term (2015-2029)				Long-term (2030-2100)			
Intermediate driver	Sub-tidal/ intertidal mudflat	Tidal marsh	Managed wetlands	Upland transition zone	Sub-tidal/ intertidal mudflat	Tidal marsh	Managed wetlands[a]	Upland transition zone
Detrimental levees and armoring; human development				X				X
Invasive species	X	X		X	X	X		
Sediment supply		X				X		
Adjacent land use for upland transgression								X
Pond maintenance water levels			X				X	
Salinity			X				X	
Levee physical integrity			X				X	
Freshwater inflow and hydrology	X	X			X	X		
Marsh size, connectivity, and complexity		X				X		

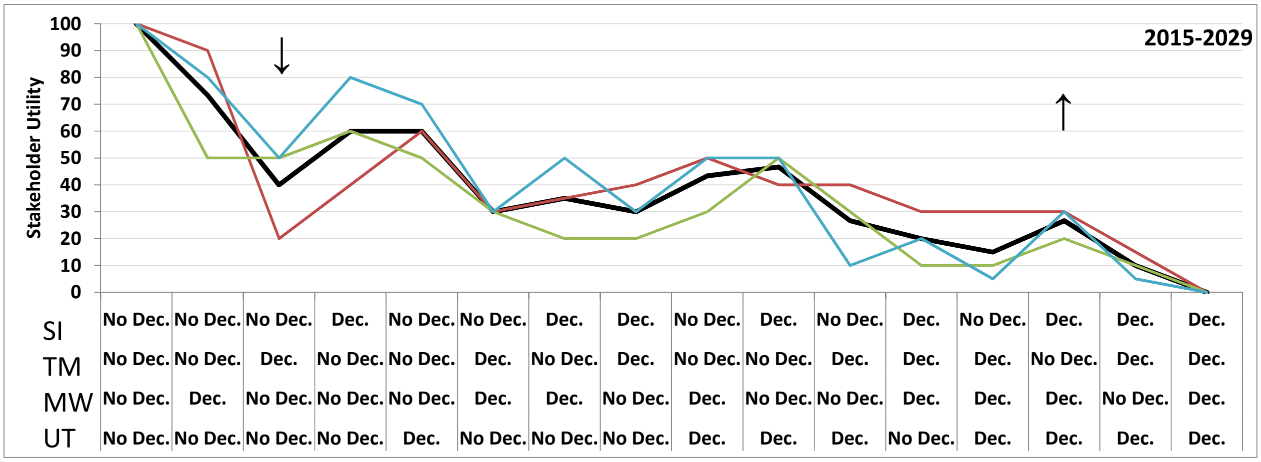
[a] Intermediate drivers here focus on structures that will be maintained in the future, as many managed wetland structures will not be maintained throughout the long-term.

5.1.5.2 *Eliciting quantitative inputs for decision models*

Working with a decision analyst and following a set of guidelines (Appendix G), the North Bay team went through an expert elicitation process to assign probabilities to outcomes for attributes represented in each ecosystem-specific influence diagram for each outcome horizon (Appendix E-1). The general methods used for the elicitation are described in section 3.5.3. The North Bay team went through two separate elicitation processes, one for attributes in the near-term and one for attributes related to the long-term outcome horizon.

5.1.6 Identifying & quantifying trade-offs

Following a set of guidelines (see section 3.6) and working with a decision analyst, North Bay team members provided utilities representing how they value possible outcomes in terms of changes in biotic integrity for the four estuarine ecosystems in the near-term (2015-2029) and in the long-term (2030-2100). North Bay stakeholders, on average, placed more value on changes in biotic integrity of tidal marsh compared to the other estuarine ecosystems (Figure 5.1.3). Ecosystem tradeoffs did not differ substantially between these time periods. There was, however, more disparity among stakeholders regarding ecosystem tradeoffs during the long-term than during the near-term horizon. When comparing tradeoffs between outcome horizons, North Bay stakeholders were on average more averse to decreasing biotic integrity in the long-term than they were in the near-term (Figure 5.1.4). These utility values, combined with the elicited probabilities for attributes in the North Bay decision tool (see section 5.1.5.2), were used to compute expected performance of each allocation option in each management horizon.



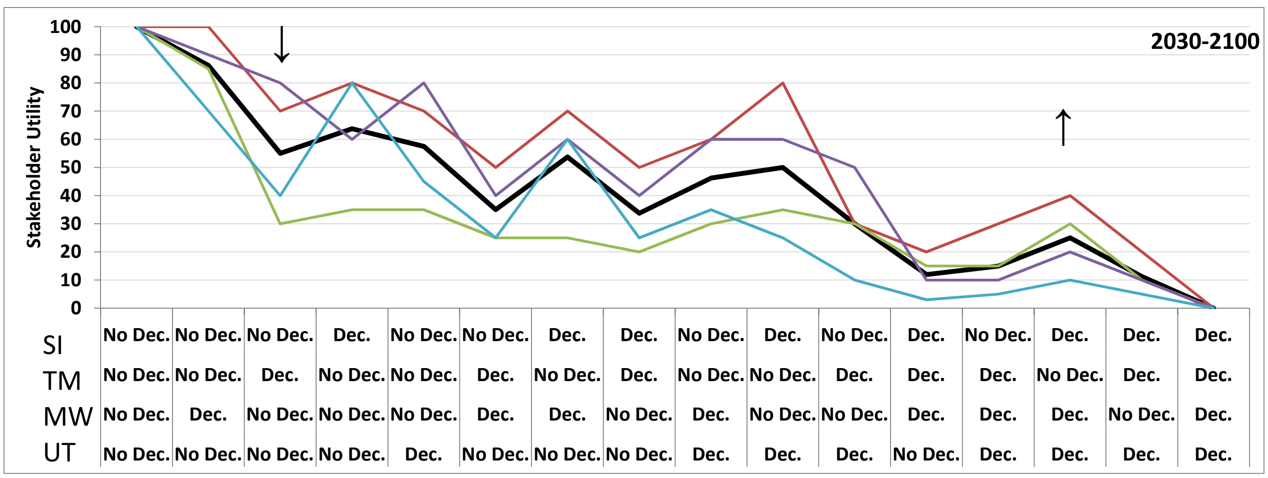
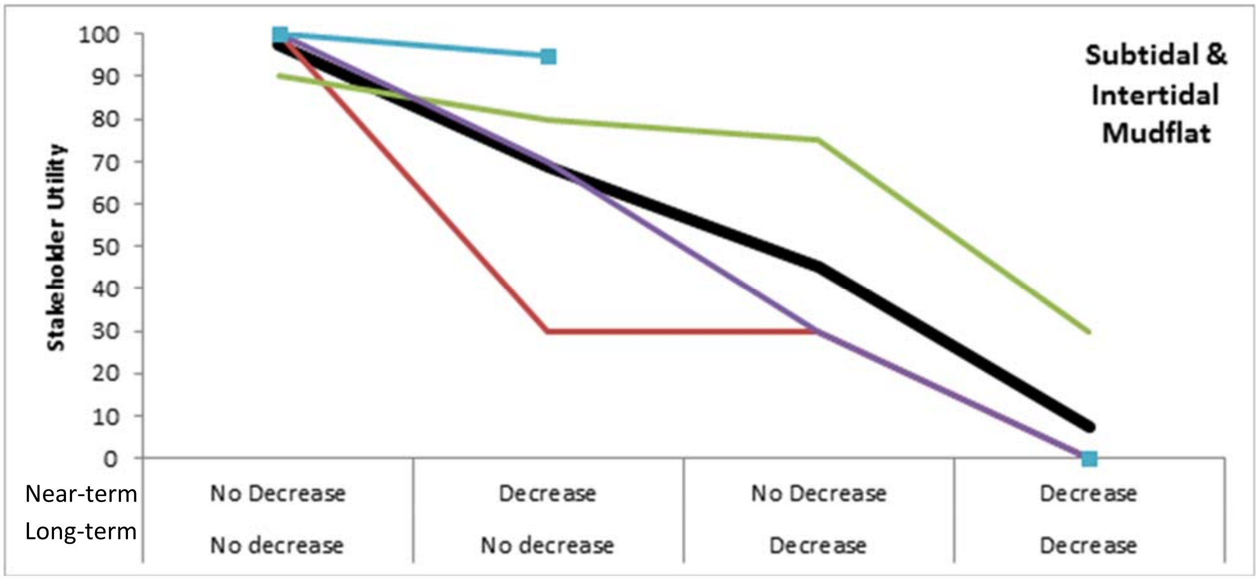


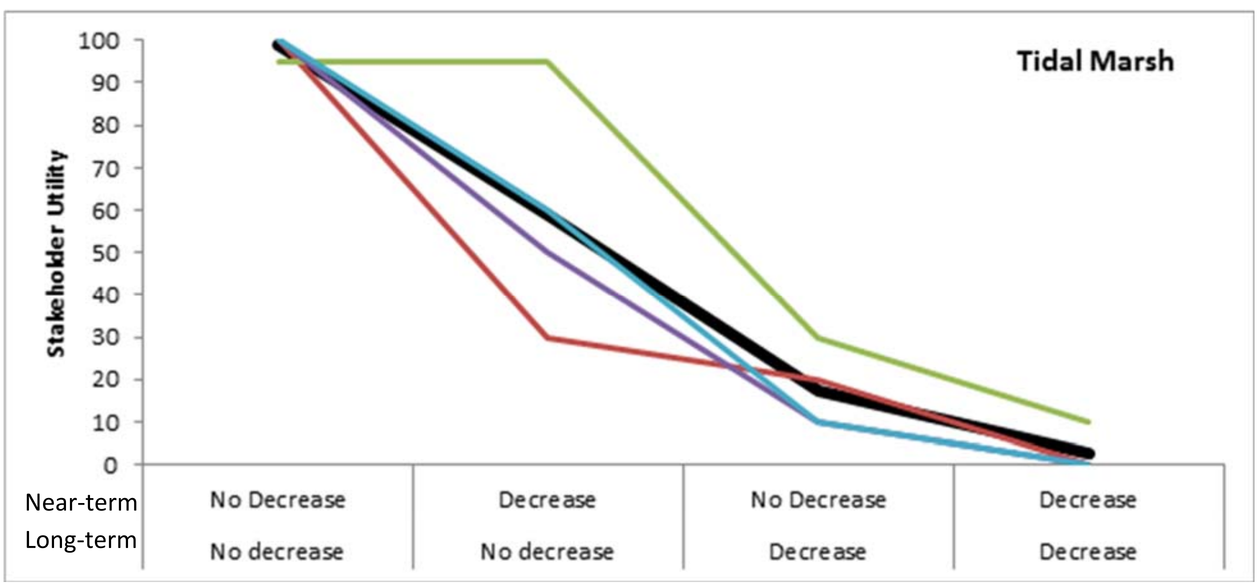
Figure 5.1.3. Stakeholder trade-offs among ecosystems in North Bay.

Tradeoffs were quantified based on an elicitation process, where stakeholders independently assigned a value (0-100) representing their preferences for possible changes in biotic integrity in each of the four focal estuarine ecosystems during the near-term (2015-2029) and long-term (2030-2100). Change in biotic integrity was defined by changes in particular biotic attributes (e.g., change in shorebird abundance) in each ecosystem. No Dec. = stable or increasing; Dec. = decreasing biotic integrity. SI=Subtidal and intertidal; UT = Upland transition; MP = Managed ponds; TM=Tidal marsh. Thick black line is the average utility value across stakeholders; colored lines represent utilities of individual stakeholders (n=3 for near-term; n=4 for long-term). Top graph is for the near term (2015-2029) and bottom is for the long-term (2030-2100) outcome horizon. The down arrow (↓) indicates a scenario where only tidal marsh has decreasing biotic integrity; up arrow (↑) indicates a scenario where only tidal marsh has stable or increasing biotic integrity. North Bay stakeholders on average valued changes in biotic integrity in tidal marsh more than in the other estuarine ecosystems.

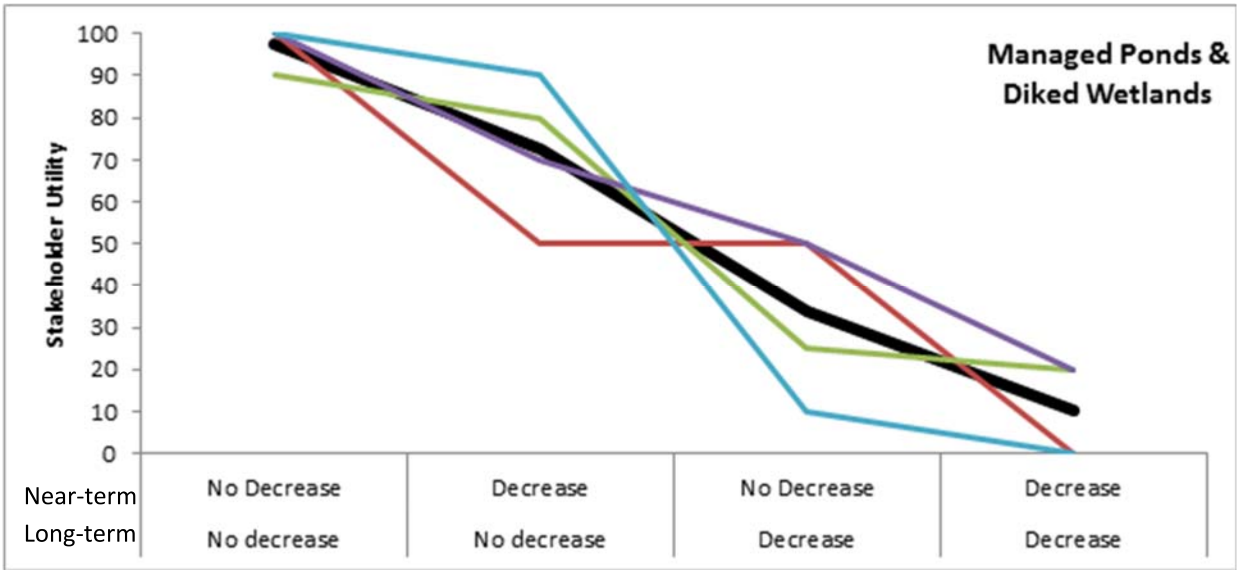
Figure 5.1.4. Stakeholder trade-offs between outcome horizons in North Bay.

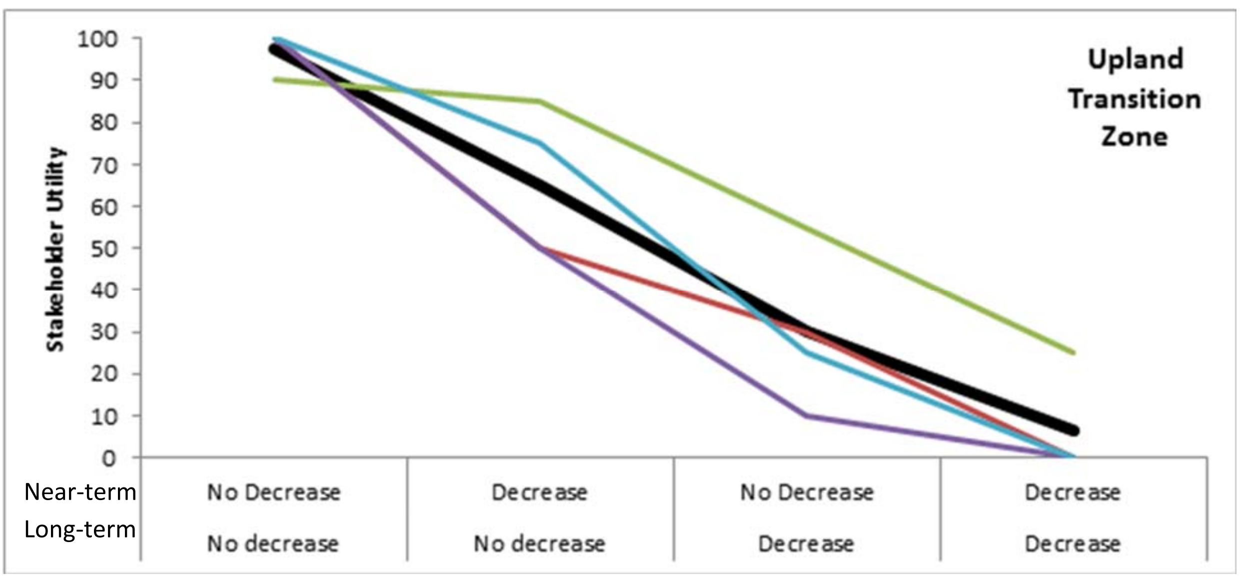
Tradeoffs were quantified based on an elicitation process, where stakeholders independently assigned a value (0-100) representing their preferences for possible changes in biotic integrity in each of the four focal estuarine ecosystems during the near-term (2015-2029) and long-term (2030-2100). Change in biotic integrity was defined by changes in particular biotic attributes (e.g., change in shorebird abundance) in each ecosystem. Thick black line is the average utility value across stakeholders; colored lines represent utilities of individual stakeholders (n=3 for near-term; n=4 for long-term). There was a missing utility value from one of the participants regarding a temporal tradeoff for subtidal and intertidal mudflat ecosystems (blue line connected by boxes). North Bay stakeholders were on average more averse to decreasing biotic integrity in the long-term than they were in the near-term.





Stakeholder trade-offs between outcome horizons in North Bay, continued.



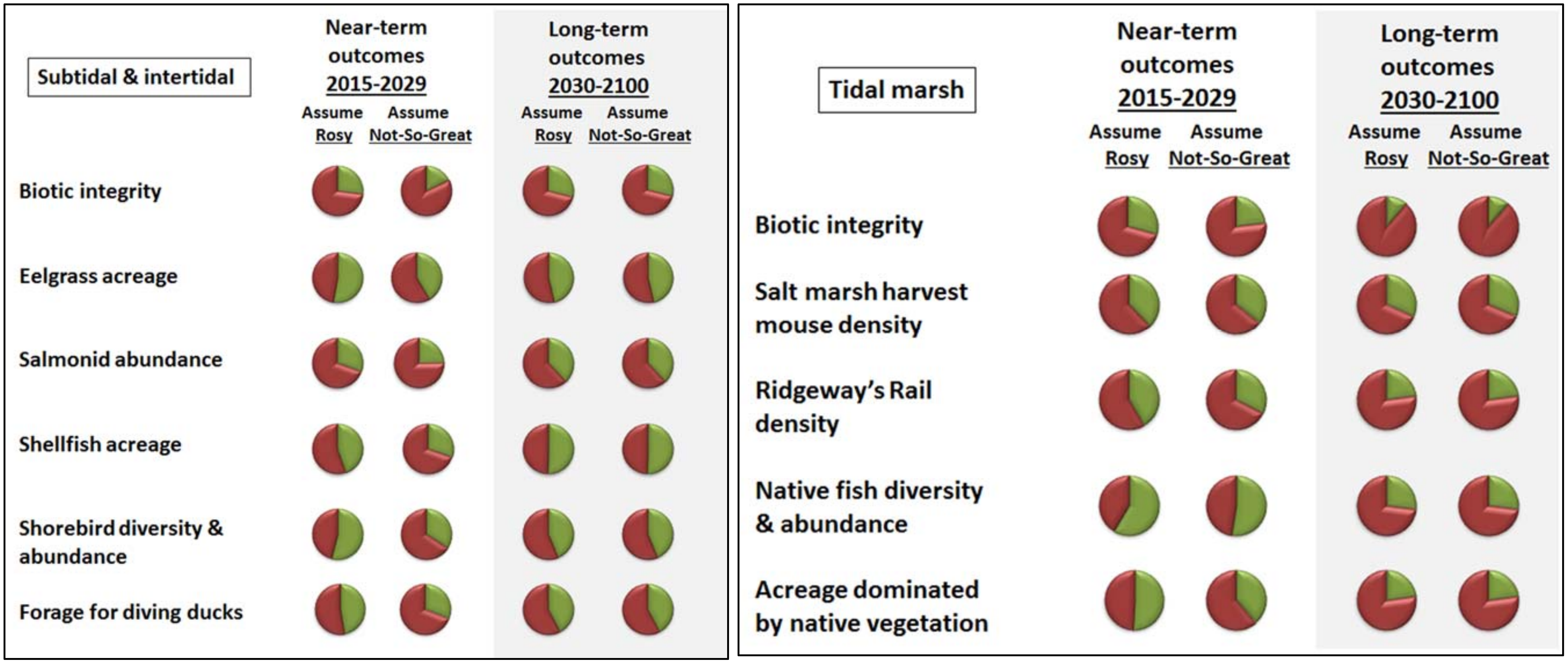


5.1.7 Identifying recommended allocations and main findings

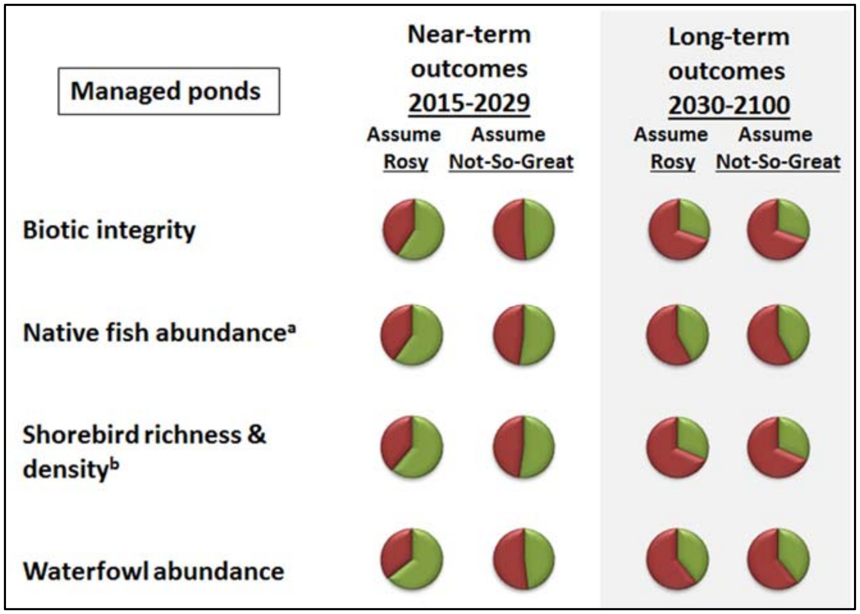
Using the averaged probabilities and utilities from North Bay team members, the subregional decision tool (see section 3.7.1; Appendix I) indicated that the recommended option in the near-term (2015-2029) and in the longer-term (2030-2050) management horizon is to implement the assume-rosy allocation (Table 5.1.4 and Table 5.1.5; see also section 3.4.1). Under this baseline set of assumptions, we can expect 6% greater performance (in terms of tradeoffs among conservation objectives in the near-term and long-term; see section 3.6) by implementing the assume-rosy allocation (53% performance expected) than by implementing the assume-not-so-great allocation (47% performance expected). Predicted outcomes were equally or more optimistic under the assume-rosy than under the assume not-so-great allocation in the near-term (Figure 5.1.5). Because none of the near-term outcomes were linked to long-term outcomes in the decision tool, predicted long-term outcomes are the same between the two near-term allocation options. For example, according to the North Bay decision tool, change in biotic integrity for tidal marsh in the near-term had no bearing on change in biotic integrity for tidal marsh (or any other factor) in the long-term. The only factors affecting long-term changes in indicators of biotic integrity were the longer-term allocation options and conditions of the external drivers in the long-term.

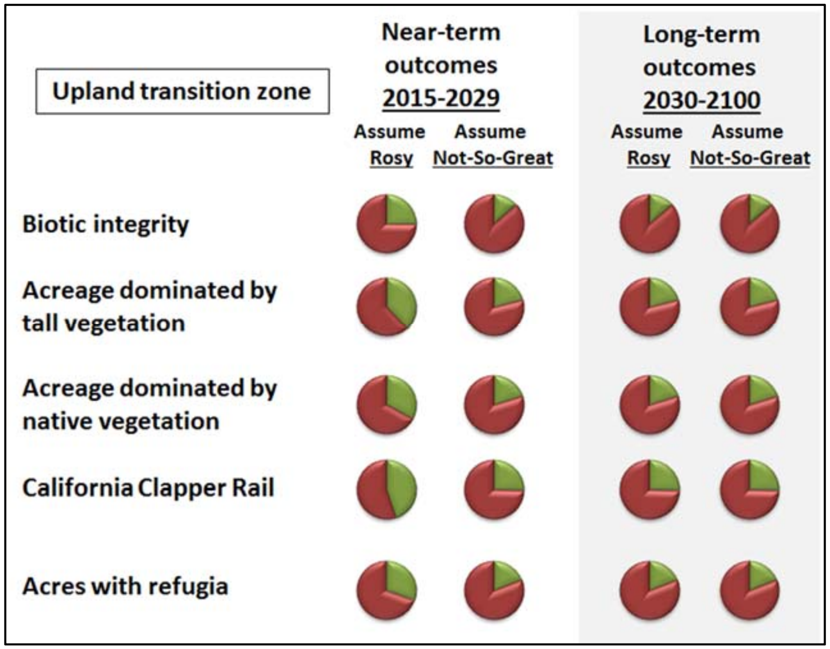
Figure 5.1.5. Predicted outcomes for biotic integrity in estuarine ecosystems of North Bay.

Predicted outcomes for biotic integrity of estuarine ecosystems of North Bay under two near-term (2015-2029) resource allocation options with contrasting assumptions resource availability and external environmental drivers from 2015 through 2100. The green area in each pie chart represents the probability that an attribute will be stable or increasing during the respective outcome horizon. Probabilities were averaged across independent inputs from 4 stakeholders for the near-term (2015-2029) and 3 stakeholders for the long-term (2030-2100) outcomes.

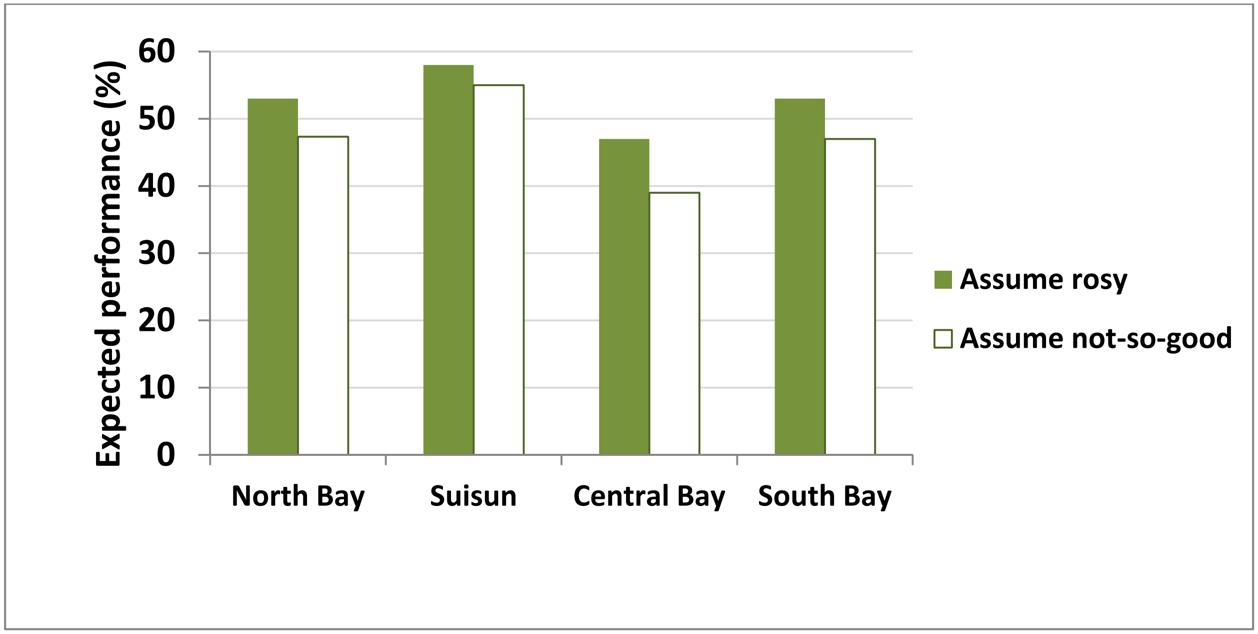


Predicted outcomes for estuarine ecosystems of North Bay (continued).





Expected performance (% chance of stable or increasing biotic integrity across ecosystems) of assume-rosy resource allocation by subregion



5.1.7.1 Sensitivity analysis and value of resolving uncertainty

The near-term (2015-2029) and longer-term (2030-2050) recommendations remained the assume-rosy allocation (Table 5.1.4 and Table 5.1.5) even when using pessimistic probabilities for external drivers (e.g., resource availability, extreme storms, rate of sea-level rise) in place of probabilities averaged across stakeholders[7]. That means, the recommendations are insensitive (i.e., robust) to uncertainties about the external drivers in the near-term (2015-2029) and long-term (2030-2100). The recommendations changed when using optimistic probabilities for effects of the assume-not-so-great allocation on all of the indicators in tidal marsh and upland transition zone (henceforth, focal uncertainties; Table 5.1.1). If all of these focal near-term uncertainties are resolved through further research and analysis, there would be at most a 5% expected gain in performance[8] with respect to tradeoffs in biotic integrity among the four estuarine ecosystems. Likewise, there is at most 5% expected gain in performance if all the focal long-term uncertainties are resolved before the longer-term decision is made. Stakeholders in North Bay should consider whether they are willing to invest more in research and analysis to reach the maximum expected gains in performance. *Unless these uncertainties are resolved, our recommendation remains to carry out the assume-rosy allocations for both time horizons.*

[7] Sensitivity analysis entailed exploring differing sets of probabilities obtained from individual stakeholders using an independent elicitation process. See section 3.7.

[8] Expected gains in performance were based on a decision-analytic approach of calculating the expected value of perfect information (Runge et al. 2011). Expected gains shown in the table reach a maximum value depending on their levels of belief in the two sets of probabilities used in the sensitivity analysis, which remain unknown.

5.2 Suisun

As mentioned above, the subregional teams adopted a general decision frame at the beginning of the stakeholder workshop (see section 3.1) within which to develop and refine their subregional decision models. The decision question for the Suisun team, then, was:

How should limited resources be allocated across time and space toward potential actions within Suisun to conserve San Francisco Bay estuarine ecosystems over the near-term (2015-2029) and long-term (2030-2100) while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?

Underlines in this decision question emphasize revised wording relative to the decision question agreed upon during plenary that applied to any subregion. The time horizons are added for clarity. The subsections below provide a description of how this decision question was addressed, culminating with recommended resource allocations for a near-term (2015-2029).

5.2.1 Engaging stakeholders and experts

Stakeholders who participated in refining the Suisun decision model following the workshop were the same the group who worked together in the workshop breakout sessions (Table 2.2.3), except for two who already had commitments to other projects and were unable to participate in the refinement of the decision model. The post-workshop team (composed of two decision analysts and three stakeholders) discussed model revisions results via webinars, phone and email.

5.2.2 Refining conservation objectives

For assigning conservation objectives[9] the Suisun team adopted the estuarine ecosystem classification that was discussed as a larger group at the workshop: subtidal and intertidal mudflats, tidal marsh, managed ponds and diked marshes, and upland transition zone (Table 3.1.2). For each ecosystem, the team defined an overarching fundamental objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) in Suisun. At the start of the workshop, stakeholders were provided a list of proposed indicators of biotic integrity that could apply to each of these ecosystems anywhere in the SF Bay Estuary (Table 3.2.2). Starting with this draft list the Suisun team initially identified 16 indicators (Table 5.2.1). This initial list was then reduced to a set of 7 indicators by considering 1) the ultimate desires of stakeholders, 2) how well an attribute could indicate ecosystem biotic integrity, 3) the complexity of the decision tool (as the number of indicators increases the tool complexity increases), 4) feasibility of measures, and

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[9] For developing alternative allocations, the Suisun team lumped tidal marsh with upland transition zone (see section 5.2.4). These two ecosystems were kept distinct for the conservation objectives in Suisun, however.

therefore feasibility of practicing adaptive management over the long-term, and 5) whether or not the indicator was already being measured in Suisun.

Table 5.2.1. Indicators of biotic integrity for estuarine ecosystems of Suisun.

Final set of 7 indicators representing biotic integrity as an ultimate desired outcome in each of four estuarine ecosystems in Suisun. Each indicator was classified as stable or increasing vs. decreasing during the near-term (2015-2029). To keep the decision tool tractable, some indicators were included implicitly rather than explicitly within the decision tool. These were documented to help the stakeholders quantify their uncertainty about changes in biotic integrity, considering that not all indicators were included explicitly. See section 4.5.2 for more explanation.

Subtidal & intertidal mudflats

1) Acreage dominated by native submerged aquatic vegetation
2) Delta smelt abundance

Implicit indicators:

- Wintering shorebird abundance
- Distribution and abundance of native shellfish beds
- Diving duck winter abundance

Tidal marsh

3) Obligate native tidal marsh bird (e.g., rails) diversity and abundance
4) Native small mammal(e.g., salt marsh harvest mouse, shrew) diversity and abundance

Implicit indicators:

- Acres of tidal marsh with optimal native plant composition
- Native fish diversity

Managed wetlands

5) Salt marsh harvest mouse abundance (index: capture efficiency)
6) Dabbling and diving duck wintering population size

Implicit indicators:

- Winter population size of waders and shorebirds

Upland transition zone

7) Acres dominated by native marsh transition zone-associated plant species

Implicit indicators:

- Obligate native tidal marsh bird diversity

- Salt marsh harvest mouse abundance (index: capture efficiency)
- Vernal pool native plant species richness

5.2.3 Refining action categories

The Suisun team used the action categories defined for the workshop as a whole (Table 3.3.1), with two exceptions. First, they combined the "manage water quality" and "manage water quantity" categories into a single "manage water" category as did other subregions (see section 6.2). Second, they added an action category called "Collect information" that represents expenditures on monitoring and research to help inform adaptive management within the near-term time frame. The team wanted to make explicit that some of the resources in Suisun would be allocated to collecting information as opposed to taking management actions or protecting acreage. The Suisun team took into consideration actions described in the Suisun Plan[10] when constructing their categories. They also assumed that the actions taken within a category would be similar to those defined in the BEHGU recommendations for Suisun (Table 5.2.3), as well as other actions that the Suisun team believed would be feasible and necessary in the region (e.g., the "manage individual wildlife species" action category consisted of strategies such as captive breeding and assisted migration).

[10] U.S. Bureau of Reclamation, U. S. Fish and Wildlife Service, and California Department of Fish and Wildlife (2014)

Table 5.2.2. Set of action categories for Suisun.

All of the action categories for Suisun were as proposed during the workshop plenary, except for the two marked with an asterisk (*). The original set of action categories were altered by 1) combining the 'manage water levels' and 'manage water quality' into one category called 'manage water' and 2) a new category 'collecting information' was added.

Action category	Suisun interpretation of action category
Protect/acquire acreage	Purchase land (e.g., fee-title) or conservation easements
Manage sediment	Managing sediment to restore/enhance base elevations: increase sediment inputs, manage local/existing sediment and elevations, design projects to maximize sediment capture and retention. Applies to diked areas and existing tidal marsh. Sediment could come from a variety of sources including levees, newly flooded/subtidal areas and dredge material
Manage wildlife/animal species	Direct management of wildlife (e.g., predator management; translocation/captive breeding). Suisun examples include control of wild pig, feral cat and invertebrate populations; wildlife relocation/translocation.
Manage vegetation	Direct management of vegetation including planting/seeding native vegetation, invasive plant control (terrestrial and aquatic). *Lepidium latifolium* is a priority threat to wetland environments of Suisun.
Manage water (quantity and quality)*	Actions aimed at water supply (movement, flows, timing) and quality (e.g., salinity). Actions include maintenance of water management infrastructure. Actions also include levee construction or maintenance, contaminant clean-up, removal of levees/berms to improve hydrology or hydrological connectivity.
Manage human disturbance	Law enforcement; restrict human recreation along/in high value areas; reroute transportation corridors away from high value areas (i.e. ferries & related impacts)
Collect information*	Actions relating to inventory, monitoring and research that support reducing uncertainties and measuring management effectiveness-true adaptive management..

Table 5.2.3. Recommended actions from BEHGU for Suisun

Cross-referencing draft recommended actions from the Baylands Ecosystem and Habitat Update with the relevant action categories and locations by ecosystem for Suisun.

	Action category						Bayland ecosystem				
	Protect acreage	Manage sediment	Manage individual wildlife	Manage for native community	Manage water	Manage human disturbance	Subtidal & intertidal	Tidal marsh & upland transition	Manged wetland	Migration Space	Water-shed
Enhance managed diked marsh areas to improve and diversify conditions for wildlife (e.g., waterfowl)(manage base soil/sediment elevations, e.g., Grizzly Island); incentivize managed wetland activities that can help benefit future tidal restoration (e.g., land/water management practices that help to limit subsidence).		X			X			X			
Enhance tidal marsh (diked/non-diked): restore tidal connections.		X			X			X	X		
Maximize availability of watershed sediment to tidal marsh and mudflats.		X			X						X
Provide natural transitions to adjacent uplands with protective buffers wherever possible for all existing and restored tidal marshes.	X	X						X			
Control Lepidium, Phragmites and other priority invasive plants				X			X	X	X		
Enhance managed marsh areas that are not restored to tidal marsh to improve waterfowl habitat				X	X			X			
Preserve/augment shallow subtidal submerged aquatic vegetation beds (e.g., eelgrass): Carquinez Strait, Carquinez Bridge to Pittsburg;				X			X				
Protect and enhance existing vernal pools and other seasonal wetlands adjacent to Montezuma Slough, in the Nurse Slough area, and north of Potrero Hills	X			X				X			

Recommended actions from BEHGU for Suisun, continued.

	Action category						Bayland ecosystem				
	Protect acreage	Manage sediment	Manage individual wildlife	Manage for native community	Manage water	Manage human disturbance	Subtidal & intertidal	Tidal marsh & upland transition	Manged wetland	Migration Space	Water-shed
Work with upstream water agencies, regulators, and users, who will also be affected by climate change, to minimize a cascading effect on downstream water users; widen flood control channels and channelized creeks to allow flood waters to spread and nourish marshes.					X						X
Maximize availability of watershed sediment in water column.		X			X						X
Where tidal marsh cannot be restored, improve water management to enhance diked wetlands through realignment of levees, drainage ditches and connecting of historic sloughs;					X				X		
Restore large areas of tidal marsh in diked and muted tidal marsh areas (Hill Slough and upper Suisun Slough areas, and on Morrow Island south of the confluence of Goodyear Slough and Suisun Slough, eastern side of Montezuma Slough, in the Nurse Slough area, and near Denverton Creek.)		X		X	X			X			
Connect large areas of restored tidal marsh with a tidal marsh corridor (e.g., along Cordelia Slough to facilitate water management on duck clubs);					X			X			
Continue hazardous material clean up (e.g., Concord Naval base)					X	X				X	
Reduce runoff of agricultural contaminants.					X	X				X	
Protect and enhance existing vernal pools and other seasonal wetlands adjacent to Montezuma Slough, in the Nurse Slough area, and north of Potrero Hills	X			X	X			X			

5.2.4 Developing resource allocation options

During plenary in the workshop, stakeholders agreed to a classification of six Bayland ecosystems where actions could be implemented (Table 3.1.2). The Suisun team modified this Bayland-wide classification by combining tidal marsh and upland transition zone, such that they would not distinguish allocations between these two ecosystems (as was done for subtidal and intertidal mudflats in the Bayland-wide classification). From their perspective, the two ecosystems were so closely linked that they could not distinguish allocations between them. For developing allocation options, the Suisun team modified the original allocation template (Table 3.4.3) to include the revised set of action categories (Table 5.2.2) and lumping of tidal marsh and upland transition zone.

The Suisun team adopted the external driver scenarios developed during the workshop plenary (Table 3.4.1 and Table 3.4.2), and based on these developed two allocation options for the near-term (2015-2029) management horizon (Table 5.2.5 and Figure 5.2.1). After 2050, sea level is expected to rise at a faster and more uncertain rate compared to the near-term horizon. Stakeholders took this into account when assigning allocation percentages for the near-term. The stakeholders noted that although removing transportation infrastructure (i.e., roads, highways, railroads) would restore upland transition zone and allow for tidal marsh to migrate upward with sea-level rise, they assumed there would never be enough resources to do the removals. This assumption led to the allocation of resources toward ecosystems other than migration space, where the removals could otherwise occur. Although the Suisun team developed allocation options for the longer-term (2030-2050) management horizon (Table 5.2.6), they did not have sufficient time to incorporate them into their decision tool.

Table 5.2.4. Justifications for resource allocations in Suisun.

Justifications for percentages under two allocation options in a near-term (2015-2029) and two allocation options in a longer-term (2030-2050) management horizon within Suisun subregion. One option assumes the future (2015-2100) will be 'rosy' for future resource availability and external environmental drivers, and the other option assumes the long-term future will be 'not-so-great'. For allocation options see Table 5.2.5 and Table 5.2.6.

	Near-term (2030-2050)		Medium-term (2030-2050)	
Action category	Rosy	Not-So-Great	Rosy	Not-So-Great
Protect acreage	Protection/acquisition of remaining tidal marsh is a focus in the near term. Need and opportunity is high relative to other ecosystems. Acquisition of uplands for marsh migration allowing for estuarine ecosystems to move upward/inland with sea-level rise. Limited amount of area with appropriate topography for marsh migration.		Increased investment in land acquisition and protection relative to near term precluding the projected increase in SLR in the latter half of the century. Relative to near-term, increased investment in migration space.	Invest in areas with remaining potential for preserving estuarine ecosystems in a high SLR scenario, allowing systems to migrate: migration space and watershed.
Manage sediment	Maintenance or active (e.g., dredge placement) restoration of marsh elevations and managed wetland levees. For example, design restoration projects to capture and retain sediment.		Focus shifts to maintaining sediment in tidal marsh and upland transition zone - helping marsh keep pace with sea level rise in the latter half of the century.	
Manage nuisance animals				
Manage vegetation	Management of invasive plant species (e.g., Lepidium, phragmites) that stress biotic integrity. Focus here is tidal marsh and managed wetlands/ponds.		Management of invasive species will continue to be a need in the long-term, whether the climate scenario is rosy or not-so-great.	
Manage water	Maintenance and repair of water management infrastructure to control water supply and quality (e.g., salinity) of managed wetlands is a major cost factor in Suisun; Restoring hydrology in tidal marsh.	The cost of water management is expected to rise, especially for managed wetlands, as extreme storm events increase in frequency or intensity and levees fail.	The cost of water management (e.g., repair/replacement of water management infrastructure) is expected to rise significantly compared to the near-term, primarily for managed wetlands, as extreme storm events increase in frequency/intensity and the sea level rise rate increases in the latter half of the century. These climatic changes will increase the challenges related to regulating water supply and quality in managed wetlands and ponds.	
Collect information	Collecting information in the near-term is essential to assessing conservation progress (monitoring), informing/refining management strategies, reducing key uncertainties (research), and supports an adaptive management framework. Explicitly called out here because collecting information is recognized as a need but is often underfunded. Examples include extracting lessons learned from restoration projects, testing managed wetland water quality BMPs, ecological effects of invasive species.		The need for collecting information and adapting strategies will continue in the long term	

Table 5.2.5. Near-term resource allocation options for Suisun.

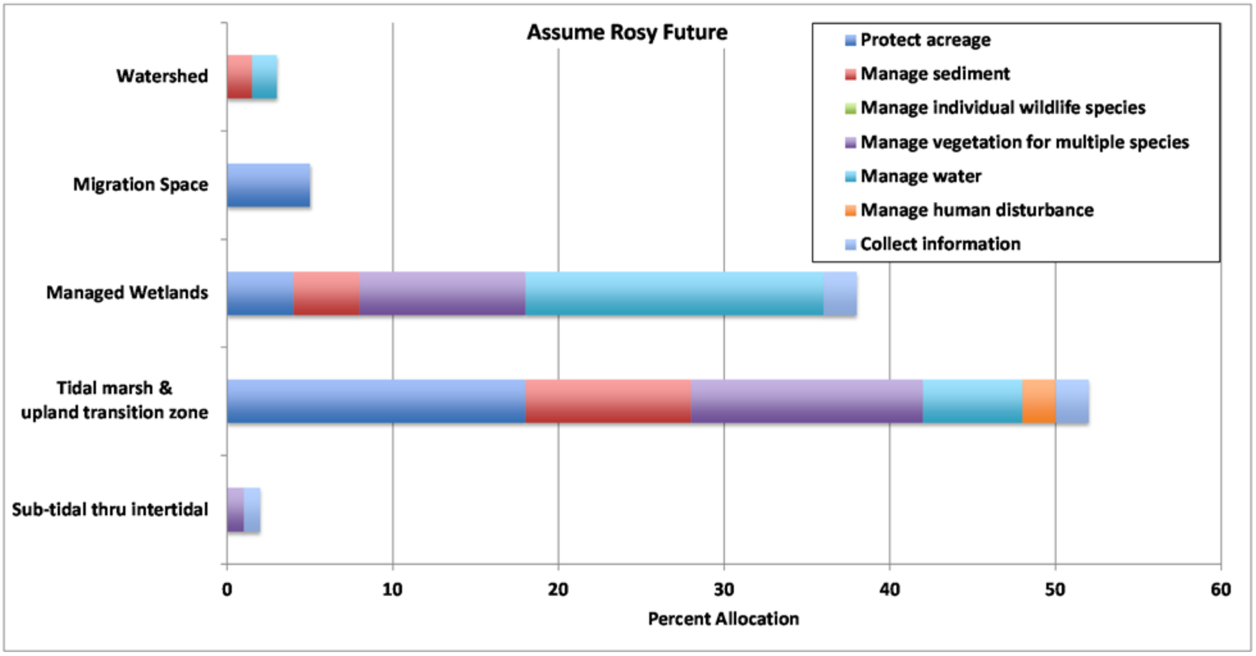
Allocation options for a near-term (2015-2029) management horizon to conserve estuarine ecosystems in Suisun from 2015-2100. Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics) (Table 3.4.1) from 2015-2100 and resource availability (Table 3.4.2) in the near-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of five focal Bayland ecosystems. Darker green shading indicates higher percentages.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh and upland transition zone	Diked baylands and managed ponds	Migration Space	Watershed	TOTAL
Assume Rosy Future						
Protect acreage	0	18	4	5	0	*27*
Manage sediment	0	10	4	0	2	*16*
Manage individual wildlife species	0	0	0	0	0	*0*
Manage vegetation for multiple species	1	14	10	0	0	*25*
Manage water	0	6	18	0	2	*26*
Manage human disturbance	0	2	0	0	0	*2*
Collect information	1	2	2	0	0	*5*
TOTAL	*2*	*52*	*38*	*5*	*3*	*100*
Assume Not-So-Great Future						
Protect acreage	0	17	4	5	0	*26*
Manage sediment	0	10	0	0	0	*10*
Manage individual wildlife species	0	0	0	0	0	*0*
Manage vegetation for multiple species	0	14	10	0	0	*24*
Manage water	0	5	30	0	0	*35*
Manage human disturbance	0	0	0	0	0	*0*
Collect information	1	2	2	0	0	*5*
TOTAL	*1*	*48*	*46*	*5*	*0*	*100*

Table 5.2.6. Longer-term resource allocation options for Suisun.

Allocation options for a longer-term (2030-2050) management horizon to conserve estuarine ecosystems in Suisun from 2030-2100. Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics) (Table 3.4.1) from 2015-2100 and resource availability (Table 3.4.2) in the longer-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of five focal Bayland ecosystems. Darker green shading indicates higher percentages.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh and upland transition zone	Diked baylands and managed ponds	Migration Space	Watershed	TOTAL
Assume Rosy Future						
Protect acreage	0	15	4	17	0	*36*
Manage sediment	0	10	0	0	1	*11*
Manage individual wildlife species	0	0	0	0	0	*0*
Manage vegetation for multiple species	0	6	7	0	1	*14*
Manage water	0	2	28	0	0	*30*
Manage human disturbance	0	1	0	2	1	*4*
Collect information	1	2	2	0	0	*5*
TOTAL	*1*	*36*	*41*	*19*	*3*	*100*
Assume Not-So-Great Future						
Protect acreage	0	0	0	9	5	*14*
Manage sediment	0	14	0	2	1	*17*
Manage individual wildlife species	0	0	0	0	0	*0*
Manage vegetation for multiple species	0	3	7	2	1	*13*
Manage water	0	0	50	0	0	*50*
Manage human disturbance	0	0	0	1	1	*2*
Collect information	1	1	1	1	0	*4*
TOTAL	*1*	*18*	*58*	*15*	*8*	*100*



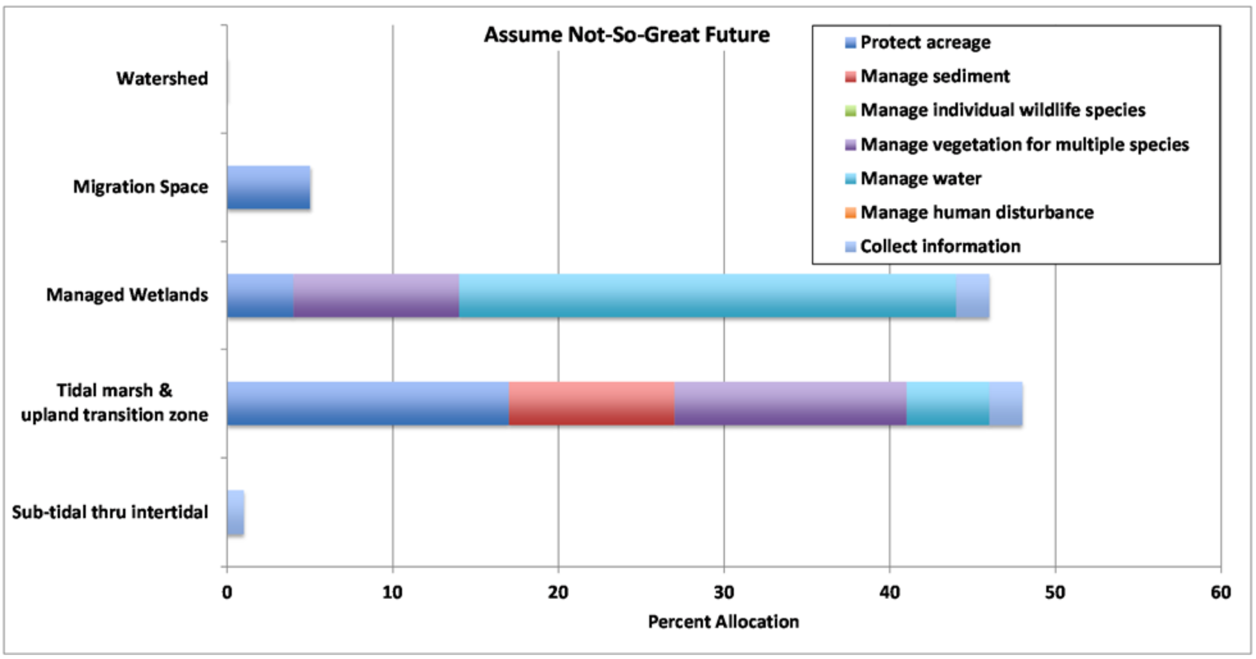


Figure 5.2.1. Near-term allocation options for Suisun.

Percent allocations to action categories (color codes in legend) within each of 6 Bayland ecosystems (y-axis) during the near-term (2015-2029), under two alternate future scenarios (2015-2100) for Suisun. See Table 3.4.1 and Table 3.4.2 for descriptions of the future scenarios.

5.2.5 Making predictions about drivers and conservation outcomes

In the workshop breakout sessions, the Suisun team began carrying out 3 of the following 4 steps:

1) (Provided in plenary: Ecosystem-specific influence diagrams linking action categories and external drivers (e.g., extreme storms) to the conservation objectives, which could apply to any subregion.)

2) Refine ecosystem-specific influence diagram for the focal subregion showing how the conservation objectives are related to indicators, and in turn how indicators are affected by action categories and external drivers via intermediate drivers.

3) Choose measurable attributes and binary levels (e.g., stable/increasing vs. decreasing) for the indicators, intermediate drivers, and external drivers within the influence diagrams.

4) Assign probabilities to possible outcomes for the conservation objectives and how they are related to indicators, and in turn how indicators are related to external drivers and resource allocation, sometimes via intermediate drivers.

Step 1 was already completed and diagrams provided to stakeholders before the breakout sessions. The Suisun team carried out steps 2-4 in an iterative fashion starting during the workshop breakouts and completed through the subregional team meetings during and after the stakeholder workshop (see section 5.2.1).

Following a set of guidelines (see section 3.5.1), the Suisun team developed an influence diagram for each of the four estuarine ecosystems in the near-term (Appendix E-2), which were modified from influence diagrams provided during plenary (Figure 4.5.1). Each ecosystem-specific influence diagram showed linkages between indicators representing biotic integrity (overarching conservation objective), intermediate drivers, external drivers (i.e., beyond the control of Suisun conservation partners), and categories of actions (Table 3.3.1).

5.2.5.1 External drivers and intermediate drivers

Attributes and thresholds between binary levels for the indicators of biotic integrity in Suisun were described in section 5.2.2. Here we describe the attributes and thresholds for each intermediate driver and each external driver that are linked directly or indirectly to the indicators in the influence diagrams (Appendix E-2).

External drivers affect estuarine ecosystems and are beyond the control of managers. The Suisun team adopted future scenarios for external environmental drivers as discussed in plenary (Table 3.4.1), and from these two external environmental drivers were identified for Suisun (Table 5.2.7). Consistent with discussions during the workshop plenary (see sections 3.4.1 and 3.5.1), the Suisun team agreed that although sea-level rise is an important external driver in the near-term (2015-2029), there is little uncertainty about its trajectory and associated impacts on estuarine ecosystems during this earlier timeframe. As such sea-level rise was considered as a constant rather than as a source of uncertainty in the decision tool, which focused on the near-term outcomes. Sea-level rise was, however, included implicitly as an external driver for the expected outcomes of the allocation outcomes over the near-term. The Suisun team also recognized that freshwater outflow from the Delta has an important impact on tidal marshes, but they believed this outflow is sufficiently correlated with extreme storm events that it did not need to be included as an explicit driver. The team adopted the Rosy and Not-So-Great scenarios developed during plenary for resource availability (Table 3.4.2), and this was included as an external driver.

Intermediate drivers influence indicators and are themselves influenced by external drivers and/or actions. Team members recognized there are many intermediate drivers that could be included, but to ensure a concise decision tool they limited the influence diagrams to the drivers having the greatest uncertainty and greatest potential impacts on biotic integrity. For Suisun, each intermediate driver had multiple dimensions and was constructed as an index (Table 5.2.8).

Table 5.2.7. External drivers for the Suisun decision tool.

For the Suisun decision tool, two external drivers were included for the near-term (2015-2029). Consistent with other subregions, sea-level rise was assumed constant during this timeframe. Unless otherwise noted, these were classified to be consistent with the scenarios discussed during the workshop plenary (Table 3.4.1).

1) *Extreme storm events*
    - Storm frequency and interval along with accompanying king tides.
2) *Extreme drought events*
    - Rosy = low intensity and frequency; Not-so-great = high intensity and frequency.

Table 5.2.8. Intermediate drivers for the Suisun decision tool.

A few intermediate drivers were considered as implicit drivers rather than being explicitly incorporated into the Suisun decision tool. These implicit drivers had one of or more of the following characteristics: 1) relatively low uncertainty about their impacts on biotic integrity; or 2) low uncertainty in how they respond to management actions.

Explicit intermediate drivers

1) *Inundation regime index*
    a. Index from optimal to suboptimal levels for water depth, duration, frequency, and timing
    b. Binary response categories: optimal vs. suboptimal for biotic integrity
    c. Relevant ecosystems: subtidal and intertidal mudflat, tidal marsh, managed wetland
2) *Salinity index*
    a. Index definition
        i. Worst: suboptimal levels for biotic integrity and consistently low variability
        ii. Best: optimal levels for biotic integrity and high seasonal variability
    b. Binary response categories: stable/increasing vs. decreasing
    c. Relevant ecosystems: subtidal and intertidal mudflat, managed wetland
3) *Sediment supply index*
    a. Binary categories: stable/increasing vs. decreasing
    b. Index varies by ecosystem:
        i. Tidal marsh: index from low to high sediment supply
        ii. Upland transition zone: index from optimal to suboptimal for submerged aquatic vegetation

Implicit intermediate drivers by ecosystem

1) *Subtidal and intertidal mudflats*
    - Abundance of invasive plants and animals
2) *Tidal marsh*
    - Index of geomorphic complexity: channel morphology, channel density, connectivity
3) *Managed wetland*
    - Acres of wetlands with optimal vegetation conditions for salt marsh harvest mouse and waterfowl
4) *Upland transition zone*
    - Abundance of invasive plants and animals
    - Index of human disturbance

5.2.5.2 Eliciting quantitative inputs for decision tools

Working with a decision analyst and following a set of guidelines (Appendix G), the Suisun team went through an expert elicitation process to assign probabilities to outcomes for attributes represented in each ecosystem-specific influence diagram for the near-term horizon (Appendix E-2). The general methods used for the elicitation are described in section 3.5.3.

5.2.6 Identifying & quantifying trade-offs

Following a set of guidelines (see section 3.6) and working with a decision analyst, Suisun team members provided utilities representing how they value possible outcomes in terms of changes in biotic integrity for the four estuarine ecosystems in the near-term (2015-2029). Suisun stakeholders, on average, valued tidal marshes and managed wetlands more than the other ecosystems (Figure 5.2.2). These utility values, combined with the elicited probabilities for attributes in the decision tool (see section 5.2.5.2), were used to compute expected performance of each allocation option.

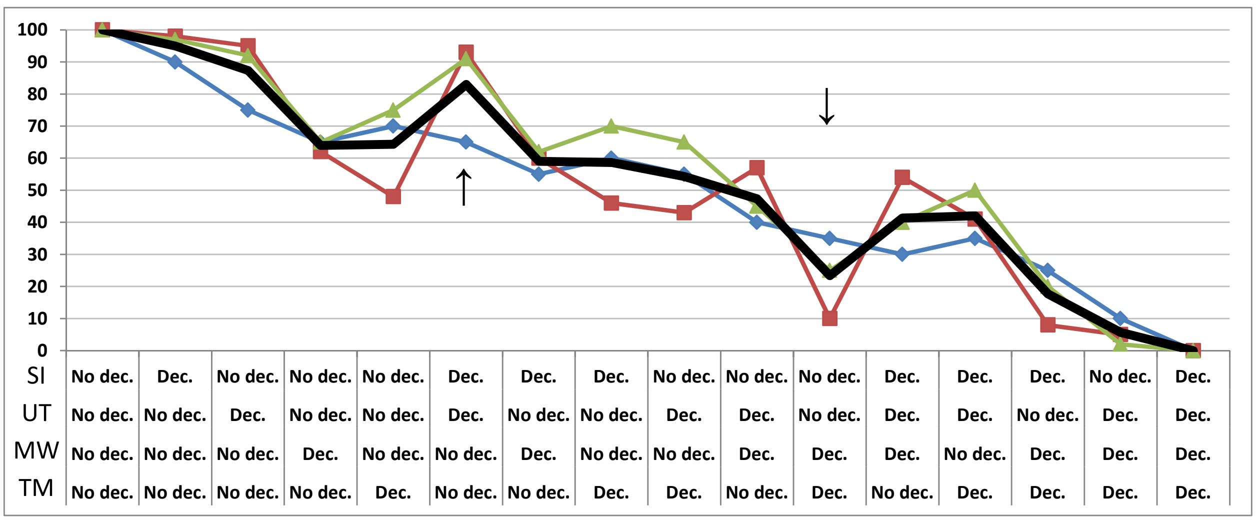


Figure 5.2.2. Stakeholder trade-offs among ecosystems and flood protection in Suisun.

Tradeoffs were quantified based on an elicitation process, where stakeholders independently assigned a value (0-100) representing their preferences for possible changes in biotic integrity in each of the four focal estuarine ecosystems during the near-term (2015-2029). Change in biotic integrity was defined by changes in particular biotic attributes (e.g., change in shorebird abundance) in each ecosystem. Thick black line is the average utility value across stakeholders; colored lines represent utilities of individual stakeholders (n=3). Inc. = increasing; Dec. = decreasing biotic integrity. SI=Subtidal and intertidal mudflat; UT = Upland transition zone; MW = Managed wetland; TM=Tidal marsh. Up arrow (↑) indicates scenario where biotic integrity is stable/increasing only in tidal marsh and managed wetland, and down arrow (↓) indicates scenario where biotic integrity is decreasing only in these two ecosystems. Suisun stakeholders on average valued changes in biotic integrity in tidal marsh and managed wetland more than in the other estuarine ecosystems.

5.2.7 Identifying recommended allocations and main findings

Using the averaged probabilities and utilities from Suisun team members, the subregional decision tool (see section 3.7.1; Appendix I) indicated that the recommended option in the near-term (2015-2029) is to implement the assume-rosy allocation (Table 5.2.5; see also section 3.4.1). Under this baseline set of assumptions, we can expect 3% greater performance (in terms of tradeoffs among ecosystems in the near-term; see section 3.6) by implementing the assume-rosy allocation (58% performance expected) than by implementing the assume-not-so-great allocation (55% performance expected). With the exception of change in salt marsh harvest mouse capture efficiency in managed wetlands, predicted outcomes were more optimistic under the assume-rosy than under the assume not-so-great allocation (

Figure 5.2.3).

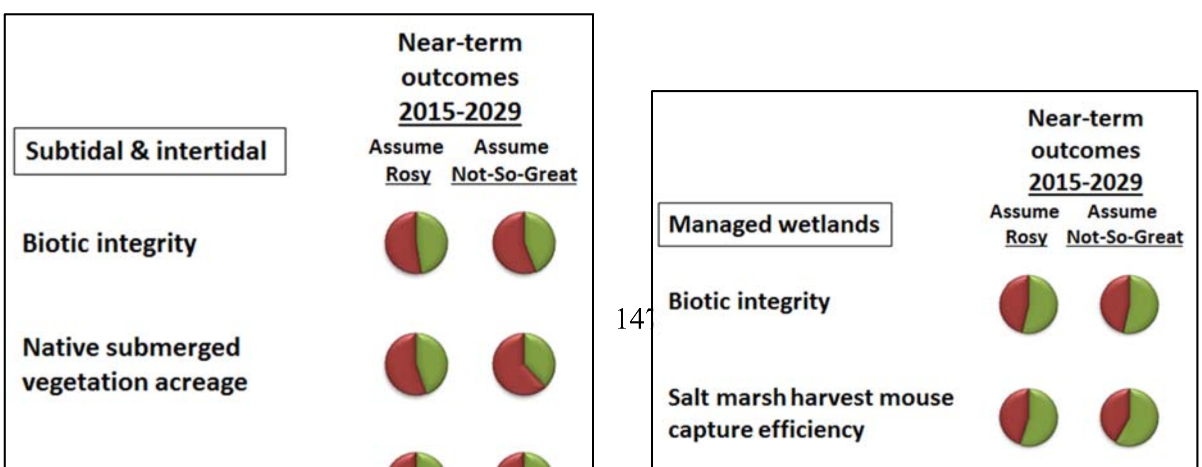
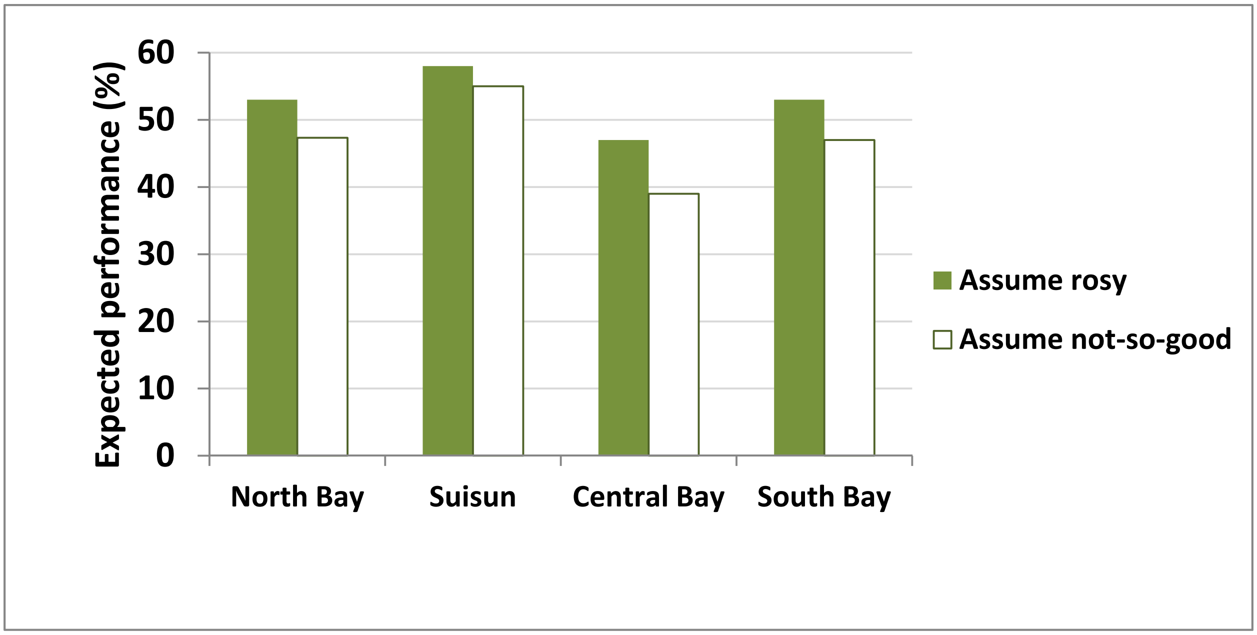


Figure 5.2.3. Predicted outcomes for biotic integrity in estuarine ecosystems of Suisun.

Predicted outcomes for biotic integrity of estuarine ecosystems of Suisun under two near-term (2015-2029) resource allocation options with contrasting assumptions resource availability and external environmental drivers from 2015 through 2100. The green area in each pie chart represents the probability that an attribute will be stable or increasing during the respective outcome horizon. Probabilities were averaged across independent inputs from 3 stakeholders.

Expected performance (% chance of stable or increasing biotic integrity across ecosystems) of assume-rosy resource allocation by subregion


Expected performance (%)
60
50
40
30
20
10
0
North Bay
Suisun
Central Bay
South Bay
Assume rosy
Assume not-so-good

5.2.7.1 Sensitivity analysis and value of resolving uncertainty

The near-term (2015-2029) recommendation remained the assume-rosy allocation (Table 5.2.5) even when using pessimistic probabilities for external drivers (e.g., resource availability, extreme storms, rate of sea-level rise) in place of probabilities averaged across stakeholders[11]. That means, the recommendations are insensitive (i.e., robust) to uncertainties about the external drivers in the near-term (2015-2029). The recommendations did each change when using optimistic probabilities for effects of the assume-not-so-great allocation on attributes of biotic integrity in tidal marsh and/or in managed ponds (Table 5.2.9). Furthermore, there would be at most 4% expected gain in performance[12] (in terms of the tradeoffs in biotic integrity among the four estuarine ecosystems) if all the uncertainties about allocation effectiveness are resolved through further research and analysis. *Unless these uncertainties are resolved, our recommendation remains to carry out the assume-rosy allocation in Suisun.*

Table 5.2.9. Expected gains after resolving uncertainties for near-term in Suisun.

Highest expected gains in performance[2] after resolving uncertainties (formally: expected value of perfect information) about effectiveness of resource allocation options in focal estuarine ecosystems of Suisun for the near-term (2015-2029).

Focal ecosystem	Uncertainties[a] to be resolved about resource allocation effectiveness in the near-term (2015-2029)	Highest expected % gain in performance after resolving focal set of uncertainties
Tidal marsh	Water inundation regime Obligate marsh bird diversity and abundance Native small mammal diversity and abundance	1.8%
Managed wetlands	Water inundation regime Salt marsh harvest mouse capture efficiency Winter duck population size	3.3%

[a] Uncertainties about changes in each of the focal attributes.

[11] Sensitivity analysis entailed exploring differing sets of probabilities obtained from individual stakeholders using an independent elicitation process. See section 3.7.

[12] Expected gains in performance were based on a decision-analytic approach of calculating the expected value of perfect information (Runge et al. 2011). Expected gains shown in the table reach a maximum value depending on their levels of belief in the two sets of probabilities used in the sensitivity analysis. These levels of belief have yet to be elicited.

5.3 Central Bay

As mentioned above, the subregional teams adopted a general decision frame at the beginning of the stakeholder workshop (see section 3.1) within which to develop and refine their subregional decision tools. The decision question for the Central Bay team, then, was:

How should limited resources be allocated across time and space toward potential actions <u>within Central Bay</u> to conserve San Francisco Bay estuarine ecosystems <u>over the near-term (2015-2029)</u> while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?

Underlines in this decision question emphasize revised wording relative to the decision question agreed upon during plenary that applied to any subregion. The time horizon is added for clarity. The subsections below provide a description of how this decision question was addressed, culminating with a recommended resource allocation for a near-term (2015-2029) management horizon. Although the original plan was develop recommendations for the longer-term (2030-2050) management horizon and to project conservation objectives over the long-term (2030-2050), the Central Bay team did not have sufficient time to complete the long-term elements of their decision tool. Although not evaluated explicitly, the team did take into account long-term (2030-2100) outcomes when designing their allocation options for the near-term (see section 5.3.4 below).

5.3.1 <u>Engaging stakeholders and experts</u>

Except for two individuals, stakeholders who participated in refining the Central Bay decision tool following the workshop differed from those who worked together in the workshop breakout sessions (Table 2.2.3). Three of the members already had commitments to other projects and were unable to participate in the refinement of the decision tool after the workshop, and we added three individuals that had previously been identified as stakeholders working in Central Bay but were not part of that group during the workshop. The post-workshop Central Bay team (composed of a decision analyst and five stakeholders) discussed model revisions and results during three 90-minute conference calls. The decision analyst also communicated with the stakeholders individually via emails and an occasional phone call.

5.3.2 Refining conservation objectives

The Central Bay team adopted the estuarine ecosystem classification that was discussed as a larger group at the workshop (Table 3.1.2), with the exception of ignoring managed wetlands due to their scarcity in this subregion. The three focal estuarine ecosystems for Central Bay, then, were: subtidal and intertidal mudflats, tidal marsh, and upland transition zone. For each ecosystem, the team defined an overarching fundamental objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) in Central Bay. At the start of the workshop, stakeholders were provided a list of proposed indicators of biotic integrity that could apply to each of these ecosystems anywhere in the SF Bay Estuary (Table 3.2.2). Starting with this draft list the Central Bay team initially identified 12 indicators (Table 5.3.1). This initial list was then reduced to a set of 7 indicators by considering 1) the importance of the measure for ultimately representing conservation success and overall ecosystem health, and 2) the complexity of the decision model (as the number of attributes increases the model complexity increases). In addition to these indicators of biotic integrity, the team also included dollars for flood protection as an attribute representing an important consideration when doing conservation in the Central Bay.

Table 5.3.1. Indicators of biotic integrity for estuarine ecosystems of Central Bay.

Final set of 7 indicators to represent increasing biotic integrity as an ultimate desired outcome in each of three focal estuarine ecosystems in Central Bay. Some indicators were included as implicit rather than explicit components of biotic integrity, to maintain a tractable decision tool.

Subtidal & intertidal mudflats

1) Increasing total mudflat acreage
2) Stable/increasing subtidal water quality[a]
3) Increasing subtidal forage fish biomass
4) Increasing subtidal acreage dominated by native living substrate

Tidal marsh

5) Tidal marsh recovery criteria are met[b]
6) Increasing plant and invertebrate biomass

Implicit indicators:

- Increasing acreage dominated by native plants
- Increasing connectivity among marshes
- Stability of native wildlife populations

Upland transition zone

7) Upland transition zone recovery criteria are met[b]

Implicit indicators:

- Increasing acreage dominated by native plants
- Stability of native wildlife populations

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[b] No trend was relevant, only whether the criteria are met in the tidal marsh recovery plan ((U.S. Fish and Wildlife Service 2013)).

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5.3.3 Refining action categories

During plenary in the workshop, stakeholders agreed to a classification of six Bayland ecosystems where actions could be implemented (Table 3.1.2). As described above, the Central Bay team removed managed wetlands from consideration due to their negligible acreage in the subregion.

The team then defined six action categories (Table 5.3.2) based on (1) the original set of action categories discussed during plenary in the workshop (Table 3.3.1); (2) draft BEHGU recommendations for Central Bay (Table 5.3.3); and (3) the team members' own knowledge of the relevant actions in the subregion. Relative to the original action categories, the team clarified the distinction between "Manage wildlife species" and "Manage vegetation" to mean that actions in the former are directed toward animal species, and actions in the latter are directed toward plant species.

Table 5.3.2. Set of action categories for Central Bay.

All of the action categories were as proposed during the workshop plenary, except for those marked with an asterisk (*).

1) *Protect acreage*: e.g. conservation easements
2) *Manage sediment* -- e.g. alter dam releases
3) *Manage individual wildlife animal species** -- take action directed at conservation of species of interest, e.g. translocation, control measures for nuisance animals
4) *Manage vegetation community for multiple wildlife species* -- e.g. plant natives, remove / treat against invasive plants
5) *Manage water levels & quality** -- e.g. change water depth
6) *Manage human disturbance* -- e.g. manage recreation access, reroute transportation corridors

Table 5.3.3. Recommended actions from BEHGU for Central Bay.

Cross-referencing draft recommended actions from the Baylands Ecosystem and Habitat Update with the relevant action categories and locations by ecosystem for Central Bay.

	Action category						Bayland ecosystem				
	Protect acreage	Manage sediment	Manage individual wildlife	Manage for native community	Manage water	Manage human disturbance	Subtidal & intertidal	Tidal marsh	Upland transition zone	Migration Space	Water-shed
Tidal marsh habitats should be restored wherever possible, but particularly at the mouths of streams, where they enter the Baylands.		X		X		X		X			
Tributary streams and riparian habitats should be protected and enhanced in conjunction with having them pass through, rather than around, tidal marshes.		X			X						X
Natural salt ponds on the East Bay shoreline should be restored, and shallow subtidal habitats (including eelgrass and oyster beds) should be protected and enhanced.	X	X		X	X	X	X	X			
Even the smallest restoration efforts should try to incorporate transition zones from intertidal habitats to adjacent terrestrial areas, as well as buffers beyond the transition zone.		X		X	X	X	X	X	X	X	
Shorebird roosting sites should be protected and enhanced.			X								
Measures to maintain and restore estuarine wetlands and their transition zones are needed, such as stabilizing the marsh edge with a coarse beach to minimize erosion, recharging the mudflat and marsh with sediment to increase the local supply, and improving sediment pathways to maximize vertical accretion at the back of the marsh.		X		X	X	X	X	X	X		
While there is critical infrastructure that will need to be protected no matter what, there are also ample opportunities for small improvements that may result in enhanced habitat corridors and better linkages for species that use the bay and baylands.	X	X		X	X	X		X	X	X	

Recommended actions from BEHGU for Central Bay, continued.

	Action category						Bayland ecosystem				
	Protect acreage	Manage sediment	Manage individual wildlife	Manage for native community	Manage water	Manage human disturbance	Subtidal & intertidal	Tidal marsh	Upland transition zone	Migration Space	Water-shed
There is a need for testing innovative and experimental approaches, that may include sediment placement, use of uncontaminated on-site fill in restoration designs, and integrated multi-habitat designs with multiple biological and physical objectives.		X		X	X	X	X	X	X		
Enhance the ecological connections between creek mouths, tidal wetlands, and subtidal offshore habitats in several areas.	X	X			X		X	X			
Living breakwaters could be created around fringing marshes to preserve and enhance unique features like native eelgrass and oyster beds.		X			X		X	X			
Partner with the industrial and residential communities along the shoreline to develop green infrastructure, which would create habitat bayward of their flood-protection levees ("horizontal levee", "living shorelines", "green infrastructure" concepts).	X	X			X		X			X	
There are major land uses such as the Port of San Francisco that will remain and need to be protected with innovative approaches that haven't yet been tried locally, such as Living Seawalls.	X				X					X	

Recommended actions from BEHGU for Central Bay, continued.

	Action category						Bayland ecosystem				
	Protect acreage	Manage sediment	Manage individual wildlife	Manage for native community	Manage water	Manage human disturbance	Subtidal & intertidal	Tidal marsh	Upland transition zone	Migration Space	Water-shed
There are opportunities for preservation, enhancement, and creation of diverse pocket habitats that could be linked together to create a sub-regional habitat corridor.	X	X		X		X	X	X	X		
Small opportunities currently exist, such as vertical enhancements in subtidal and intertidal areas where there is hardscape (living seawalls, substrate improvements to docks, etc.).		X			X		X				
There are ample opportunities to remove deterrents to existing habitats such as improvements to tidegate management, removal of derelict creosote pilings, contaminated soils, derelict boats; and plans could be improved to remove trash that terminates in the Bay.		X			X	X	X	X			
Create habitat along flood control channels, flood plain habitat, or off channel habitat, or low elevation marsh/wetland restoration, including upstream opportunities even though they are limited.		X		X	X			X	X		
Invasive Spartina control remains a critical priority, constraint, and important consideration for some existing marsh sites and for restoration planning in this segment. Progress is being made and should continue towards eradication and prevention of new infestations of invasive Spartina at sites like Eastshore State Park.				X				X			

5.3.4 Developing resource allocation options

For developing allocation options, the Central Bay team modified the original allocation template (Table 3.4.3) to include the revised set of action categories (Table 5.3.2) and ecosystem classification that ignored managed wetlands. The team then used this customized allocation template to develop two allocation options for the near-term (2015-2029) management horizons (Table 5.3.4 and Figure 5.3.1).

The Central Bay team adopted the external driver scenarios developed during the workshop plenary (Table 3.4.1 and Table 3.4.2), and based on these developed two allocation options for the near-term (2015-2029) management horizon (Table 5.3.4) to best achieve the conservation objectives (see section 5.3.2 above) for Central Bay from 2015-2100. After 2050, sea level is expected to rise at a faster and more uncertain rate compared to the near-term horizon. Stakeholders took this into account when assigning allocation percentages for the near-term.

There were essentially three steps for developing each allocation option. First, the team assigned a percentage that would be allocated to each of the five focal Bayland ecosystems such that the percentages added to 100. Here, we refer to these as ecosystem-level allocations. Second, they assigned a percentage of the ecosystem-level allocation that would be allocated to each of the six action categories within a particular ecosystem such that these percentages also added to 100. They repeated this second step for each of the five ecosystems. To calculate each of the $5 \times 6 = 30$ ecosystem-action-category specific percentages, they took the product of the ecosystem-level allocation and the percentage allocated to an action category within that ecosystem and divided by 100. This rescaling ensured that the 30 percentages would add to 100, while maintaining the ecosystem-level allocations and relative allocations among action categories within each ecosystem. Specific justifications for how the resources were allocated under each of the options were not documented.

Table 5.3.4. Near-term resource allocation options for Central Bay.

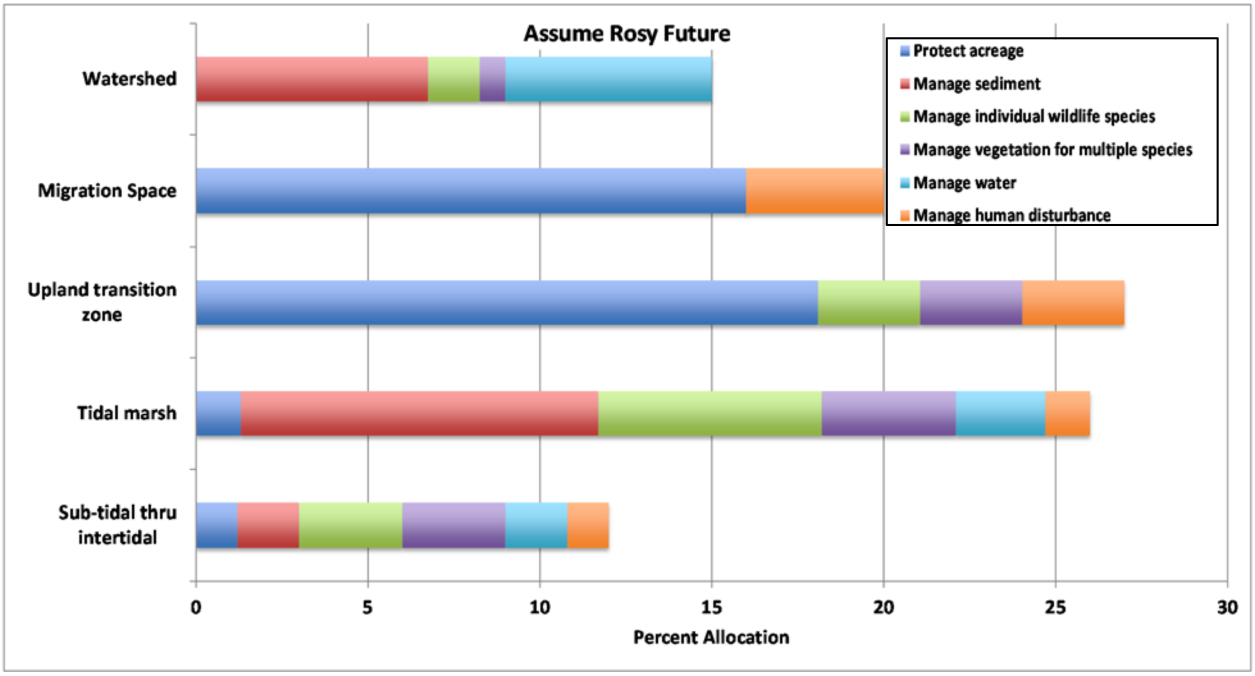
Allocation options for a near-term (2015-2029) management horizon to conserve estuarine ecosystems in Central Bay from 2015-2100. Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics)(Table 3.4.1) from 2015-2100 and resource availability (Table 3.4.2) in the near-term. Each cell value represents a percentage of resources allocated to one of six action categories in one of five focal Bayland ecosystems. Darker green shading indicates higher percentages.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh	Upland transition zone	Migration Space	Watershed	TOTAL
Assume Rosy Future						
Protect acreage	1	1	18	16	0	*37*
Manage sediment	2	10	0	0	7	*19*
Manage individual wildlife species	3	7	3	0	2	*14*
Manage vegetation for multiple species	3	4	3	0	1	*11*
Manage water	2	3	0	0	6	*10*
Manage human disturbance	1	1	3	4	0	*9*
TOTAL	*12*	*26*	*27*	*20*	*15*	*100*
Assume Not-So-Great Future						
Protect acreage	1	2	20	20	0	*43*
Manage sediment	2	14	0	0	0	*16*
Manage individual wildlife species	3	9	3	0	0	*15*
Manage vegetation for multiple species	3	5	3	0	0	*11*
Manage water	2	4	0	0	0	*5*
Manage human disturbance	1	2	3	5	0	*11*
TOTAL	*10*	*35*	*30*	*25*	*0*	*100*

Table 5.3.5. Longer-term resource allocation options for Central Bay.

Allocation options for a longer-term (2030-2050) management horizon to conserve estuarine ecosystems in Central Bay from 2030-2100. Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics) (Table 3.4.1) from 2015-2100 and resource availability (Table 3.4.2) in the longer-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of five focal Bayland ecosystems. Darker green shading indicates higher percentages.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh	Upland transition zone	Migration Space	Watershed	TOTAL
Assume Rosy Future						
Protect acreage	3	1	13	8	0	*24*
Manage sediment	4	10	0	0	7	*21*
Manage individual wildlife species	6	6	5	0	2	*19*
Manage vegetation for multiple species	6	4	5	0	1	*16*
Manage water	4	3	0	0	6	*12*
Manage human disturbance	3	1	3	2	0	*9*
TOTAL	*25*	*25*	*25*	*10*	*15*	*100*
Assume Not-So-Great Future						
Protect acreage	1	1	12	32	0	*45*
Manage sediment	1	8	0	0	0	*9*
Manage individual wildlife species	1	5	8	2	0	*16*
Manage vegetation for multiple species	1	3	8	2	0	*14*
Manage water	1	2	0	0	0	*3*
Manage human disturbance	1	1	3	9	0	*14*
TOTAL	*5*	*20*	*30*	*45*	*0*	*100*



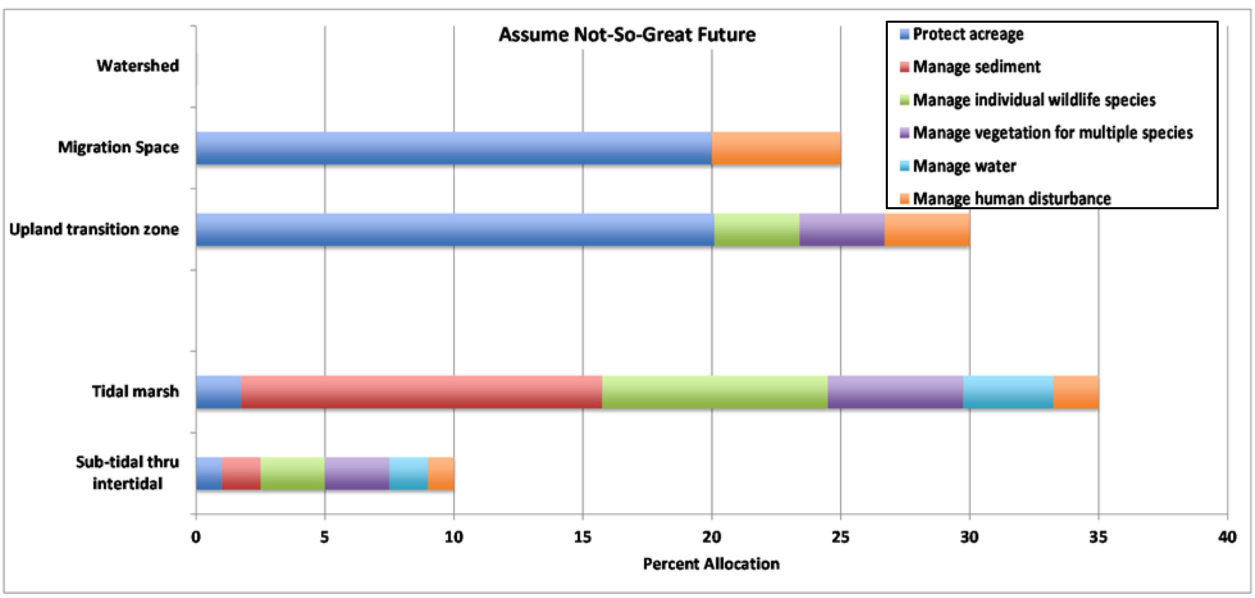


Figure 5.3.1. Near-term allocation options for Central Bay.

Percent allocations to action categories (color codes in legend) within each of 6 Bayland ecosystems (y-axis) during the near-term (2015-2029), under two alternate future scenarios (2015-2100) for Central Bay. See Table 3.4.1 and Table 3.4.2 for descriptions of the future scenarios.

5.3.5 Making predictions about drivers and conservation outcomes

In the workshop breakout sessions, the Central Bay team began carrying out 3 of the following 4 steps:

1) (Provided in plenary: Ecosystem-specific influence diagrams linking action categories and external drivers (e.g., extreme storms) to the conservation objectives, which could apply to any subregion.)

2) Refine ecosystem-specific influence diagram for the focal subregion showing how the conservation objectives are related to indicators, and in turn how indicators are affected by action categories and external drivers via intermediate drivers.

3) Choose measurable attributes and binary levels (e.g., stable/increasing vs. decreasing) for the indicators, intermediate drivers, and external drivers within the influence diagrams.

4) Assign probabilities to possible outcomes for the conservation objectives and how they are related to indicators, and in turn how indicators are related to external drivers and resource allocation, sometimes via intermediate drivers.

Step 1 was already completed and diagrams provided to stakeholders before the breakout sessions. The Central Bay team carried out steps 2-4 in an iterative fashion starting during the workshop breakouts and completed through the subregional team meetings during and after the stakeholder workshop (see section 5.3.1).

Following a set of guidelines (see section 3.5.1), the Central Bay team developed an influence diagram for each of three focal estuarine ecosystems in the near-term (Appendix E-3), which were modified from influence diagrams provided during plenary (Figure 4.5.1). Each ecosystem-specific influence diagram showed linkages between indicators representing biotic integrity (overarching conservation objective), intermediate drivers, external drivers (i.e., beyond the control of Central Bay conservation partners), and categories of actions (Table 3.3.1).

5.3.5.1 External drivers and intermediate drivers

Attributes and thresholds between binary levels for the indicators of the conservation objectives in Central Bay were described in section 5.3.2. Here we describe the attributes and thresholds for each intermediate driver and each external driver that are linked directly or indirectly to the indicators in the influence diagrams (Appendix E-3).

External drivers affect estuarine ecosystems and are beyond the control of managers. The Central Bay team adopted future scenarios for external environmental drivers as discussed in plenary (Table 3.4.1), and from these two external environmental drivers were identified for Central Bay (Table 5.3.6). Consistent with discussions during the workshop plenary (see sections 3.4.1 and 3.5.1), the Central Bay team agreed that although sea-level rise is an important external driver in the near-term

(2015-2029), there is little uncertainty about its trajectory and associated impacts on estuarine ecosystems during this earlier timeframe. As such sea-level rise was considered as a constant rather than as a source of uncertainty in the decision tool, which focused on the near-term outcomes. Sea-level rise was, however, included implicitly as an external driver for the expected outcomes of the allocation outcomes over the long-term (2030-2100). The team adopted the Rosy and Not-So-Great scenarios developed during plenary for resource availability (Table 3.4.2), and this was included as an external driver.

Intermediate drivers influence indicators and are themselves influenced by external drivers and/or actions. Team members recognized there are many intermediate drivers that could be included, but to ensure a concise decision tool they limited the influence diagrams to the intermediate drivers (Table 5.3.7) having the greatest uncertainty and greatest potential impacts on the indicators of biotic integrity.

Table 5.3.6. External drivers for the Central Bay decision tool.

For the Central Bay decision tool, two external drivers were included for the near-term (2015-2029). Consistent with other subregions, sea-level rise was assumed constant during this timeframe. Unless otherwise noted, these were classified to be consistent with the scenarios discussed during the workshop plenary (Table 3.4.1).

1) *Extreme weather events*
    - Frequency and intensity of droughts, storms, along with accompanying king tides.
2) *Temperature of air and water*
    - Normal = matching recent patterns vs. warmer

Table 5.3.7. Intermediate drivers for the Central Bay decision tool.

Intermediate drivers were included for all three focal estuarine ecosystems unless otherwise noted. A few intermediate drivers were considered as implicit drivers rather than being explicitly incorporated into the Central Bay decision tool. These implicit drivers had one of or more of the following characteristics: 1) relatively low uncertainty about their impacts on biotic integrity; or 2) low uncertainty in how they respond to management actions.

Explicit intermediate drivers

1) *Human disturbance* – e.g., recreation, pollution; all three ecosystems
2) *Human infrastructure and development* – e.g., transportation, buildings; all three ecosystems
3) *Sediment supply* – tidal marsh only

Implicit intermediate drivers

1) *Freshwater inflow*: affected by extreme storms and precipitation
2) *Invasive and nuisance species*: reduction of invasive plant and animal species is under partial control of management
3) *Contaminant levels*: tidal marsh only

5.3.5.2 Eliciting quantitative inputs for decision tools

Working with a decision analyst the Central Bay team went through an expert elicitation process to assign probabilities to outcomes for attributes represented in each ecosystem-specific influence diagram for the near-term (Appendix E-3). The general methods used for the elicitation are described in section 3.5.3.

5.3.6 Identifying & quantifying trade-offs

Following a set of guidelines (see section 3.6) and working with a decision analyst, Central Bay team members provided utilities representing how they value possible outcomes in terms of changes in flood protection dollars along with biotic integrity for the four estuarine ecosystems in the near-term (2015-2029). Central Bay stakeholders, on average, valued tidal marshes the most followed by subtidal and intertidal mudflats, upland transition zone, and they placed the lowest value on flood-protection dollars (Figure 5.3.2). These utility values, combined with the elicited probabilities for attributes in the decision tool (see section 5.3.5.2), were used to compute expected performance of each allocation option in each management horizon.

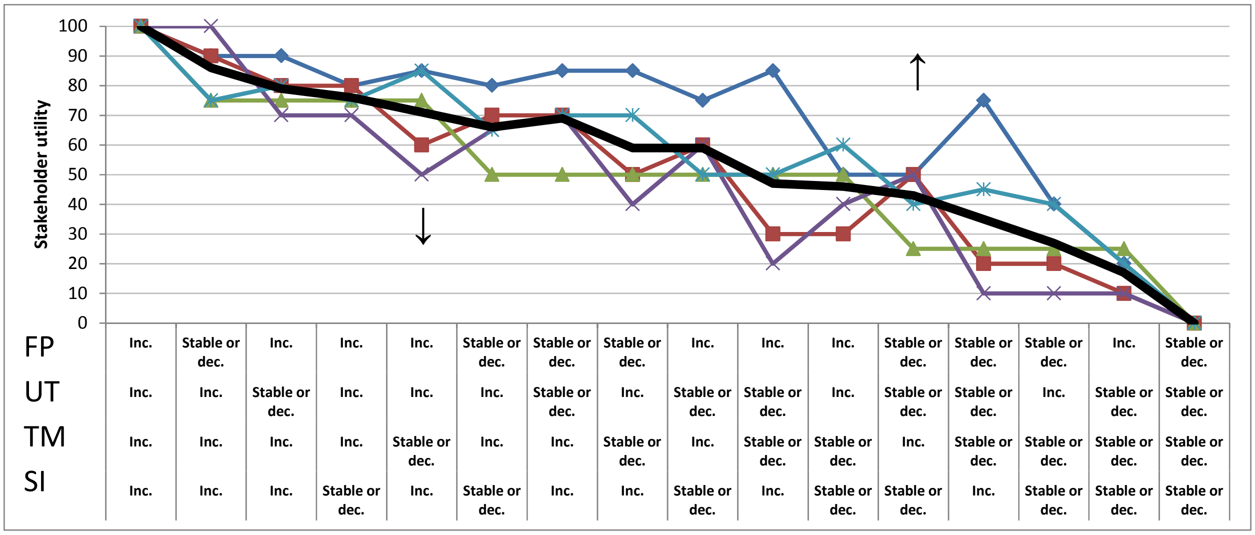


Figure 5.3.2. Stakeholder trade-offs among ecosystems and flood protection in Central Bay.

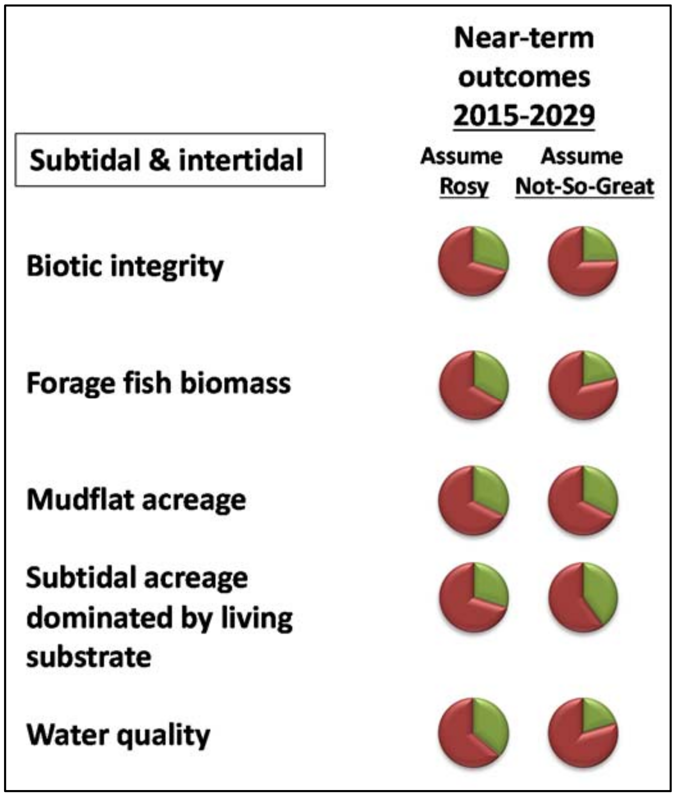
Tradeoffs were quantified based on an elicitation process, where stakeholders independently assigned a value (0-100) representing their preferences for possible changes in flood protection funds and changes in biotic integrity in each of the three focal estuarine ecosystems during the near-term (2015-2029). Change in biotic integrity was defined by changes in particular biotic attributes (e.g., change in water quality) in each ecosystem. Inc. = increasing; dec. = decreasing. FP = Flood protection dollars; UT = Upland transition zone biotic integrity; TM=Tidal marsh biotic integrity; SI=Subtidal and intertidal mudflat biotic integrity. Solid thick black line is the average utility value across stakeholders; colored lines represent utilities of individual stakeholders (n=5). The down arrow (↓) indicates a scenario where only tidal marsh has decreasing biotic integrity; up arrow (↑) indicates a scenario where only tidal marsh has stable or increasing biotic integrity. Central Bay stakeholders on average valued changes in biotic integrity in tidal marsh more than in the other estuarine ecosystems.

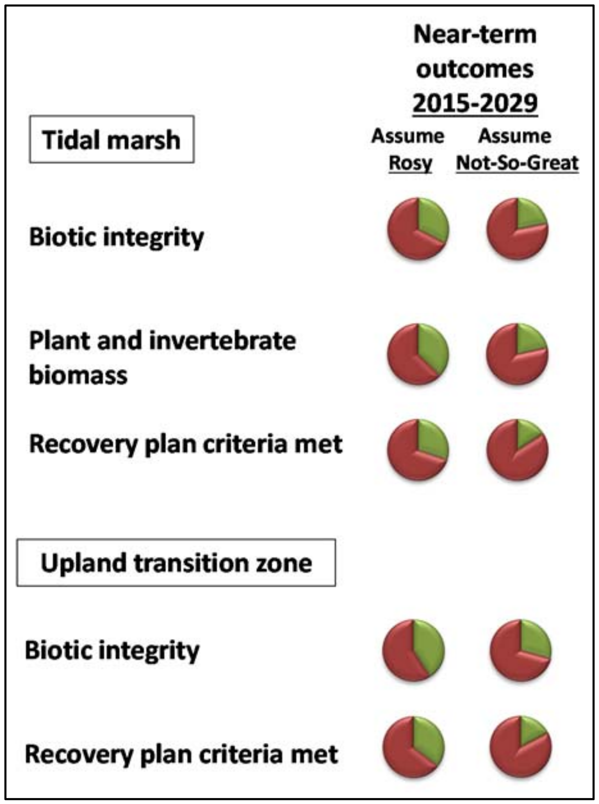
5.3.7 Identifying recommended allocations and main findings

Using the averaged probabilities and utilities from Central Bay team members, the subregional decision tool (see section 3.7.1; Appendix I) indicated that the recommended option in the near-term (2015-2029) is to implement the assume-rosy allocation (Table 5.3.4; see also section 3.4.1). Under this baseline set of assumptions, we can expect 8% greater performance (in terms of tradeoffs among conservation objectives in the near-term) by implementing the assume-rosy allocation (47% performance expected) than by implementing the assume-not-so-great allocation (39% performance expected). With the exception of changes in mudflat acreage and in acreage dominated by living substrate, predicted outcomes were more optimistic under the assume-rosy than under the assume not-so-great allocation (Figure 5.3.3).

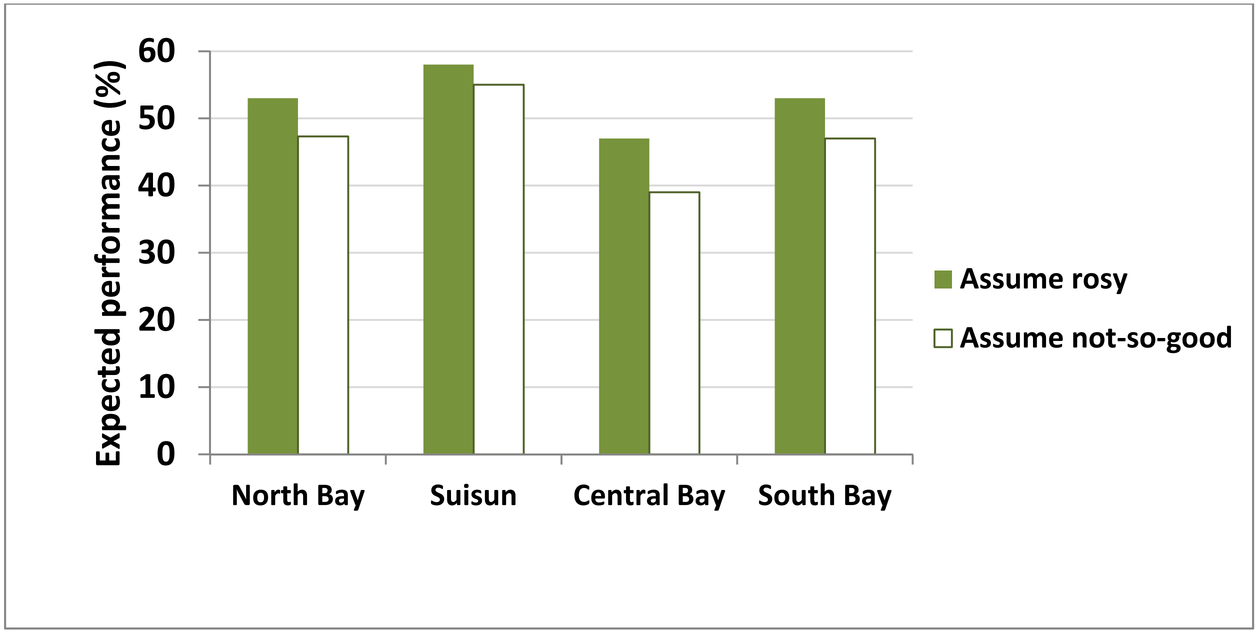
Figure 5.3.3. Predicted outcomes for biotic integrity in estuarine ecosystems of Central Bay.

Predicted outcomes for biotic integrity of estuarine ecosystems of Central Bay under two near-term (2015-2029) resource allocation options with contrasting assumptions resource availability and external environmental drivers from 2015 through 2100. The green area in each pie chart represents the probability that an attribute will be stable or increasing during the respective outcome horizon. Probabilities were averaged across independent inputs from 5 stakeholders working in Central Bay.





Expected performance (% chance of stable or increasing biotic integrity across ecosystems) of assume-rosy resource allocation by subregion



5.3.7.1 Sensitivity analysis and value of resolving uncertainty

The near-term (2015-2029) recommendation remained the assume-rosy allocation (Table 5.3.4) even when using pessimistic probabilities for external drivers (i.e., resource availability, extreme weather, and temperature of air and water) in place of probabilities averaged across stakeholders[13]. That means, the recommendations are insensitive (i.e., robust) to uncertainties about the external drivers in the near-term (2015-2029). The recommendation did each change when using optimistic probabilities for effects of the assume-not-so-great allocation on drivers and indicators of biotic integrity in tidal marsh, subtidal, and intertidal mudflat ecosystems (Table 5.3.8). There would be at most 5% expected gain in performance[14] (in terms of the tradeoffs in biotic integrity among the four estuarine ecosystems) if all uncertainties in these focal ecosystems are resolved through further research and analysis. Likewise, there is an 8% expected gain in performance if all uncertainties about effectiveness of the allocation options are resolved. Stakeholders in Central Bay should consider whether they are willing to invest more in research and analysis to reach the maximum expected gains in performance. *Unless these uncertainties are resolved, our recommendation remains to carry out the assume-rosy allocations for both time horizons.*

Table 5.3.8. Expected gains after resolving uncertainties for near-term in Central Bay.

There is a 5% expected gain in performance[2] after resolving uncertainties (formally: expected value of perfect information) about effectiveness of resource allocation options in tidal marsh, subtidal, and intertidal mudflat ecosystems for the near-term (2015-2029) in Central Bay.

Focal ecosystem	Uncertainties[a] to be resolved about resource allocation effectiveness in the near-term (2015-2029)
Subtidal and intertidal mudflat	Mudflat acreage Water quality Forage fish biomass Subtidal acreage dominated by living substrate
Tidal marsh	Recovery criteria being met by 2029 Plant and invertebrate biomass

[a] Uncertainties about changes in each of the focal attributes, except for recovery criteria which are projected at 2029 rather than projecting a trend.

[13] Sensitivity analysis entailed exploring differing sets of probabilities obtained from individual stakeholders using an independent elicitation process. See section 3.7.

[14] Expected gains in performance were based on a decision-analytic approach of calculating the expected value of perfect information (Runge et al. 2011). Expected gains shown in the table reach a maximum value depending on their levels of belief in the two sets of probabilities used in the sensitivity analysis. These levels of belief have yet to be elicited.

5.4 South Bay

As mentioned above, the subregional teams adopted a general decision frame at the beginning of the stakeholder workshop (see section 3.1) within which to develop and refine their subregional decision tools. The decision question for the South Bay team, then, was:

How should limited resources be allocated across time and space toward potential actions within South Bay to conserve San Francisco Bay estuarine ecosystems over the near-term (2015-2029) and long-term (2030-2100) while accounting for uncertainties and constraints regarding climate change and other factors such as management effectiveness, regulations, recreation, and sediment dynamics?

Underlines in this decision question emphasize revised wording relative to the decision question agreed upon during plenary that applied to any subregion. The time horizons are added for clarity. The subsections below provide a description of how this decision question was addressed, culminating with recommended resource allocations for a near-term (2015-2029) and a longer-term (2030-2050) management horizon.

5.4.1 Engaging stakeholders and experts

Stakeholders who participated in refining the South Bay decision tool following the workshop were the same the group who worked together in the workshop breakout sessions (Table 2.2.3), except for two who already had commitments to other projects and were unable to participate in the refinement of the decision tool. The post-workshop team (composed of a decision analyst and four stakeholders) discussed model revisions and results during ten 90-minute webinars that occurred approximately once per month. The decision analyst also communicated with the stakeholders individually via emails and an occasional phone call.

5.4.2 Refining conservation objectives

The South Bay team adopted the estuarine ecosystem classification that was discussed as a larger group at the workshop (Table 3.1.2), with the exception of ignoring diked marshes due to their scarcity in this subregion. Although diked marshes (distinct from managed ponds, although combined in the Bayland-wide classification) represent an important ecosystem in South Bay, they occupy a small percentage of acreage in this subregion. The team opted to exclude diked marsh from the set of conservation objectives for South Bay in the interest of keeping the decision tool feasible to populate with information and to analyze. The three four estuarine ecosystems for South Bay, then, were: subtidal and intertidal mudflats, tidal marsh, managed ponds, and upland transition zone.

For each estuarine ecosystem, the team defined an overarching fundamental objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) in South Bay. At the start of the workshop, stakeholders were provided a list of proposed indicators of biotic integrity that could apply to each of these ecosystems anywhere in the SF Bay Estuary (Table 3.2.2). Starting with this draft list the South Bay team identified 15 indicators (Table 5.4.1), which were chosen considering 1) the ultimate desires of stakeholders, 2) measurable attributes that represent biotic integrity, and 3) the complexity of the decision tool (as the number of indicators increases the tool complexity increases). In addition to these 15 attributes, the team also included a requirement to avoid flooding of infrastructure to represent an important consideration when doing conservation in the South Bay. As long as this requirement is met, the overarching objective in South Bay is to maximize biotic integrity in the four estuarine ecosystems over the near- and long-term.

Table 5.4.1. Indicators of biotic integrity for estuarine ecosystems of South Bay.

Final set of 15 indicators to represent stable or increasing biotic integrity as an ultimate desired outcome in each of four estuarine ecosystems in South Bay. Unless otherwise noted by an asterisk (*), each indicator was classified as being stable or increasing vs. decreasing during each outcome horizon. Unless otherwise noted, the same indicator was used for both the near-term (2015-2029) and long-term (2030-2100) outcome horizons.

Subtidal & Intertidal Mudflats

1) Harbor seal abundance
2) Diving duck abundance
3) Shellfish and eelgrass acreage
4) Winter shorebird abundance

Tidal Marsh

5) Ensure 1999 Bayland Goals for tidal marsh acreage, size, and connectivity are met*
6) Abundance of Ridgway's Rail and salt marsh harvest mouse
7) Dabbling duck abundance

Managed Ponds

8) Abundance of small and medium shorebirds
9) Snowy plover abundance
10) Breeding waterbird abundance
11) Diving duck abundance
12) Dabbling duck abundance
13) Abundance of birds that are salt-pond specialists

Upland Transition Zone

14) Ridgway's Rail abundance
15) Acreage dominated by…
    a. tall vegetation (near-term, 2015-2029)
    b. by native plant species (long-term, 2030-2100)

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5.4.3 Refining action categories

During plenary in the workshop, stakeholders agreed to a classification of six Bayland ecosystems where actions could be implemented (Table 3.1.2). As described in the previous section (5.4.2), the South Bay team modified the original "managed wetlands" ecosystem to focus on managed ponds rather than all managed wetlands including diked areas.

The team then defined seven action categories (Table 5.4.2) based on (1) the original set of action categories discussed during plenary in the workshop (Table 3.3.1); (2) draft BEHGU recommendations for South Bay (Table 5.4.3); and (3) the team members' own knowledge of the relevant actions in the subregion. Relative to the original action categories, the team added an action category called "Restore acreage" that represents expenditures on capital costs for infrastructure and staffing needed to conduct a restoration project, distinguishing this from other action categories representing annual expenditures on operations and maintenance of (multi-year) restoration projects. The team also ignored management actions targeted at individual wildlife species other than actions against nuisance animals.

Table 5.4.2. Set of action categories for South Bay.

All of the action categories were as proposed during the workshop plenary, except for those marked with an asterisk (*). Categories starting with "Manage" reflect costs for operation and maintenance of long-term restoration projects.

1) *Protect acreage*: e.g. conservation easements
2) *Manage sediment* -- e.g. alter dam releases
3) *Manage nuisance animal species** -- e.g. remove / treat against invasives and overabundant native wildlife species
4) *Manage vegetation community for multiple wildlife species* -- e.g. plant natives, remove / treat against invasives
5) *Manage water levels & quality* -- e.g. change water depth
6) *Manage human disturbance* -- e.g. manage recreation access, reroute transportation corridors
7) *Restore acreage** -- includes capital costs (infrastructure, staff) for long-term restoration projects

Table 5.4.3. Recommended actions from BEHGU for South Bay.

Cross-referencing draft recommended actions from the Baylands Ecosystem and Habitat Update with the relevant action categories and locations by ecosystem for South Bay.

	Action category							Bayland ecosystem					
	Protect acreage	Manage sediment	Manage nuisance animals	Manage vegetation	Manage water	Restore acreage	Manage human disturbance	Subtidal & intertidal	Tidal marsh	Managed pond	Upland transition zone	Migration Space	Water-shed
All types of tidal marshes should be connected by wide corridors along the perimeter of the Bay.	X					X			X				
Complexes of managed ponds, managed to optimize shorebird and waterfowl support, should be interspersed throughout the subregion in locations appropriate for long-term operations and maintenance.			X		X					X			
There should be natural transitions from mudflat through tidal marsh to adjacent terrestrial habitats wherever possible. This may include filling in existing baylands to create upland transition zones.	X	X	X	X		X	X	X	X	X	X	X	
Undeveloped lands adjacent to the Bay should be protected and upland transition zones created adjacent to flood-risk management levees.	X	X				X					X	X	
Reconnect local tributaries more directly to the tidal baylands.		X			X	X							X
Subtidal habitats such as eelgrass beds and oyster reefs should be created wherever possible, especially along the Hayward shoreline.			X	X		X	X	X					
Naturalistic, unmanaged saline ponds (facsimiles of historical, hyper-saline backshore pannes) should be restored, especially on the Hayward shoreline.	X					X			X				
Coarse beaches should be created, where appropriate, to reduce bay-edge erosion of marshes.		X				X			X				
Adjacent moist grasslands, particularly those with vernal pools, should be protected and improved for wildlife.	X		X	X		X						X	
Riparian vegetation and willow groves should be protected and restored wherever possible.	X			X		X							X

5.4.4 Developing resource allocation options

During plenary in the workshop, stakeholders agreed to a classification of six Bayland ecosystems where actions could be implemented (Table 3.1.2). The South Bay team adopted this classification with the exception of ignoring diked wetlands within the managed wetlands classification when developing their allocation options.

The team also adopted the external driver scenarios developed during the workshop plenary (Table 3.4.1 and Table 3.4.2), and based on these developed a pair of allocation options for the near-term (2015-2029) (Table 5.1.4) and another pair of allocation options for the longer-term (2030-2050) (Table 5.1.5) management horizon to best achieve the conservation objectives (see section 5.1.2 above) for South Bay from 2015-2100. In the long-term horizon (2030-2100), sea level is expected to rise at a faster and more uncertain rate compared to the near-term horizon. Stakeholders took this into account when assigning allocation percentages.

There were essentially two steps for developing each allocation option. First, the team assigned a score (0 = none, 1 = low, 2 = medium, 3 = high) to each action-category-ecosystem combination, representing a qualitative ordering of how much would be allocated to each action category and the ecosystem where it would be implemented. The team then increased or decreased some or all of these original entries until the total of the allocations equaled 100, so that each value represented expenditures as a percentage of total resources available. The team considered how (to which action category) and where (in which ecosystem) resources should be allocated to conserve biotic integrity of the estuary under a given scenario for the future (Table 5.4.4).

Table 5.4.4. Justifications for resource allocations in South Bay.

Justifications for percentages under two allocation options in a near-term (2015-2029) and two allocation options in a medium-term (2030-2050) management horizon within South Bay. One option assumes the long-term future (2030-2100) will be 'rosy' for future resource availability and external environmental drivers, and the other option assumes the long-term future will be 'not-so-great'. For allocation options see Table 5.4.5 and Table 5.4.6; for full description of future scenarios see Table 3.4.1 and Table 3.4.2).

	Near-term (2030-2050)		Medium-term (2030-2050)	
Action category	Rosy	Not-So-Great	Rosy	Not-So-Great
Protect acreage	-	Purchase some adjacent uplands[a] for conversion/protection in migration space, allowing for estuary to move upward with sea-level rise.	Land value will decrease somewhat because of sea-level rise, so adjacent uplands become cheaper[a] for conversion/protection in migration space allowing for estuary to move upward with sea-level rise.	-
Manage sediment	-	-	Change policies that would allow for filling in some managed ponds[b] and possibly abandoned adjacent urban areas to create migration space and upland transition zone to allow marshes to move upward with sea-level rise. Expensive to manage sediment in tidal marsh, subtidal, and intertidal ecosystems, but with great benefits for ecosystem integrity.	With faster sea-level rise, subtidal and intertidal ecoystems would persist without any management investment.
Manage nuisance animals	Compared to most other action categories, managing nuisance animals is inexpensive and is required on refuges regardless of available funding & climate change.			
Manage vegetation	-	-	Expensive to manage vegetation in upland transition zone, but important to have beneficial native plants to prepare those areas for marsh migration	-
Manage water	-	-	Expensive to manage water in salt ponds, but has great benefits for ecosystem integrity.	-

Table continued on next page.

Justifications for resource allocations in South Bay, continued.

Action category	Near-term (2030-2050) Rosy	Near-term (2030-2050) Not-So-Great	Medium-term (2030-2050) Rosy	Medium-term (2030-2050) Not-So-Great
Restore acreage	Important to invest in restoring managed ponds during the near-term		Very expensive to restore acreage, but this is the last chance to restore tidal marsh before sea-level rise accelerates after 2050. Most expensive managed ponds should be restored by 2029, so only maintenance costs needed 2030-2050.	Without sufficient funds to fill managed ponds and/or acquire and protect migration space, better to invest in restoring acreage. Tidal marsh is most expensive due to permitting and planning costs, but managed ponds and upland transition zone also need restoration.
Manage human disturbance	Compared to most other action categories, managing human disturbance is inexpensive and is required on refuges regardless of available funding & climate change.			

[a] Most adjacent lands highly urbanized and not worth protecting. Even if the land itself is cheap, the costs needed to remove infrastructure are often prohibitive.

[b] Filling managed ponds is less expensive than removing infrastructure from adjacent urban areas, but many managed ponds are projected to be completely submerged with sea-level rise.

Table 5.4.5. Near-term resource allocation options for South Bay.

Allocation options for a near-term (2015-2029) management horizon to conserve estuarine ecosystems in South Bay from 2015-2100. Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics, resource availability) from 2015-2100 and resource availability in the near-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of six Bayland ecosystems. Darker green shading indicates higher percentages.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh	Managed ponds	Upland transition zone	Migration Space	Watershed	TOTAL
Assume Rosy Future							
Protect acreage	0	1	5	5	5	0	*16*
Manage sediment	0	5	0	5	1	3	*14*
Manage nuisance animals	1	1	1	1	0	0	*4*
Manage vegetation for multiple species	0	3	3	5	1	0	*12*
Manage water	0	0	4	1	0	0	*5*
Manage human disturbance	0	1	1	1	0	0	*3*
Restore acreage	1	20	12	10	0	3	*46*
TOTAL	*2*	*31*	*26*	*28*	*7*	*6*	*100*
Assume Not-So-Great Future							
Protect acreage	0	1	5	5	10	0	*21*
Manage sediment	0	1	0	1	1	3	*6*
Manage nuisance animals	0	1	1	1	0	0	*3*
Manage vegetation for multiple species	0	1	1	1	1	0	*4*
Manage water	0	0	8	1	0	0	*9*
Manage human disturbance	0	1	1	1	0	0	*3*
Restore acreage	1	25	15	10	0	3	*54*
TOTAL	*1*	*30*	*31*	*20*	*12*	*6*	*100*

Table 5.4.6. Longer-term resource allocation options for South Bay.

Allocation options for a longer-term (2030-2050) management horizon to conserve estuarine ecosystems in South Bay over the long-term (2030-2100). Stakeholders built the options under contrasting assumptions (Rosy vs. Not-So-Great) about environmental drivers (e.g., sediment dynamics, resource availability) and resource availability in the longer-term. Each cell value represents a percentage of resources allocated to one of seven action categories in one of six Bayland ecosystems. Darker green shading indicates higher percentages.

Action Category	Sub-tidal/ intertidal mudflat	Tidal marsh	Managed ponds	Upland transition zone	Migration Space	Watershed	TOTAL
Assume Rosy Future							
Protect acreage	0	1	5	5	15	0	*26*
Manage sediment	10	10	1	5	1	1	*28*
Manage nuisance animals	1	1	1	1	0	0	*4*
Manage vegetation for multiple species	0	3	2	4	1	0	*10*
Manage water	0	0	7	1	0	0	*8*
Manage human disturbance	0	1	1	1	0	0	*3*
Restore acreage	1	5	2	5	7	1	*21*
TOTAL	*12*	*21*	*19*	*22*	*24*	*2*	*100*
Assume Not-So-Great Future							
Protect acreage	0	1	5	5	5	0	*16*
Manage sediment	0	5	0	5	1	3	*14*
Manage nuisance animals	1	1	1	1	0	0	*4*
Manage vegetation for multiple species	0	3	3	5	1	0	*12*
Manage water	0	0	4	1	0	0	*5*
Manage human disturbance	0	1	1	1	0	0	*3*
Restore acreage	1	20	12	10	0	3	*46*
TOTAL	*2*	*31*	*26*	*28*	*7*	*6*	*100*

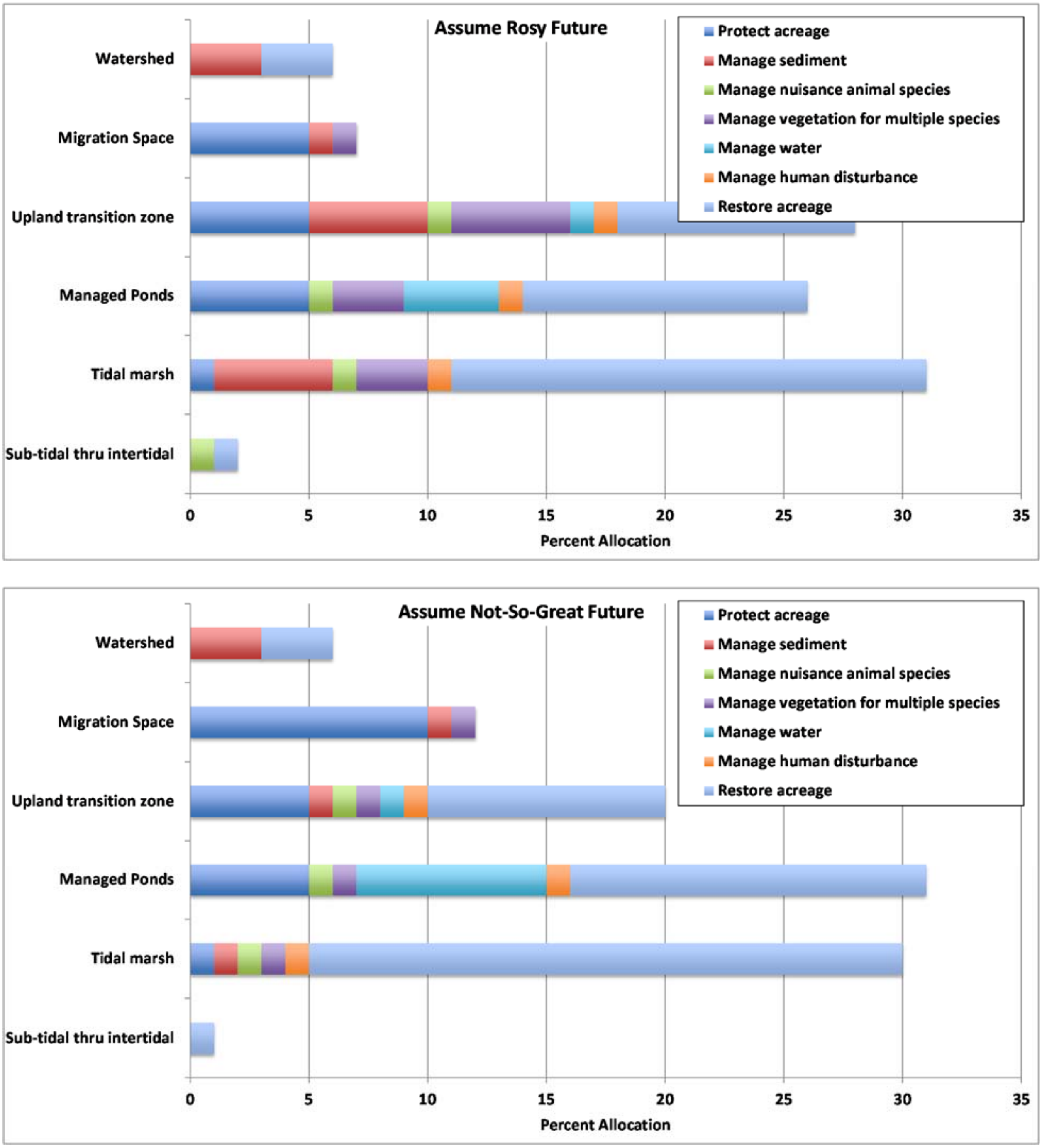

Figure 5.4.1. Near-term allocation options for South Bay.

Percent allocations to action categories (color codes in legend) within each of 6 Bayland ecosystems (y-axis) during the near-term (2015-2029), under two alternate future scenarios (2015-2100) for South Bay. See Table 3.4.1 and Table 3.4.2 for descriptions of the future scenarios.

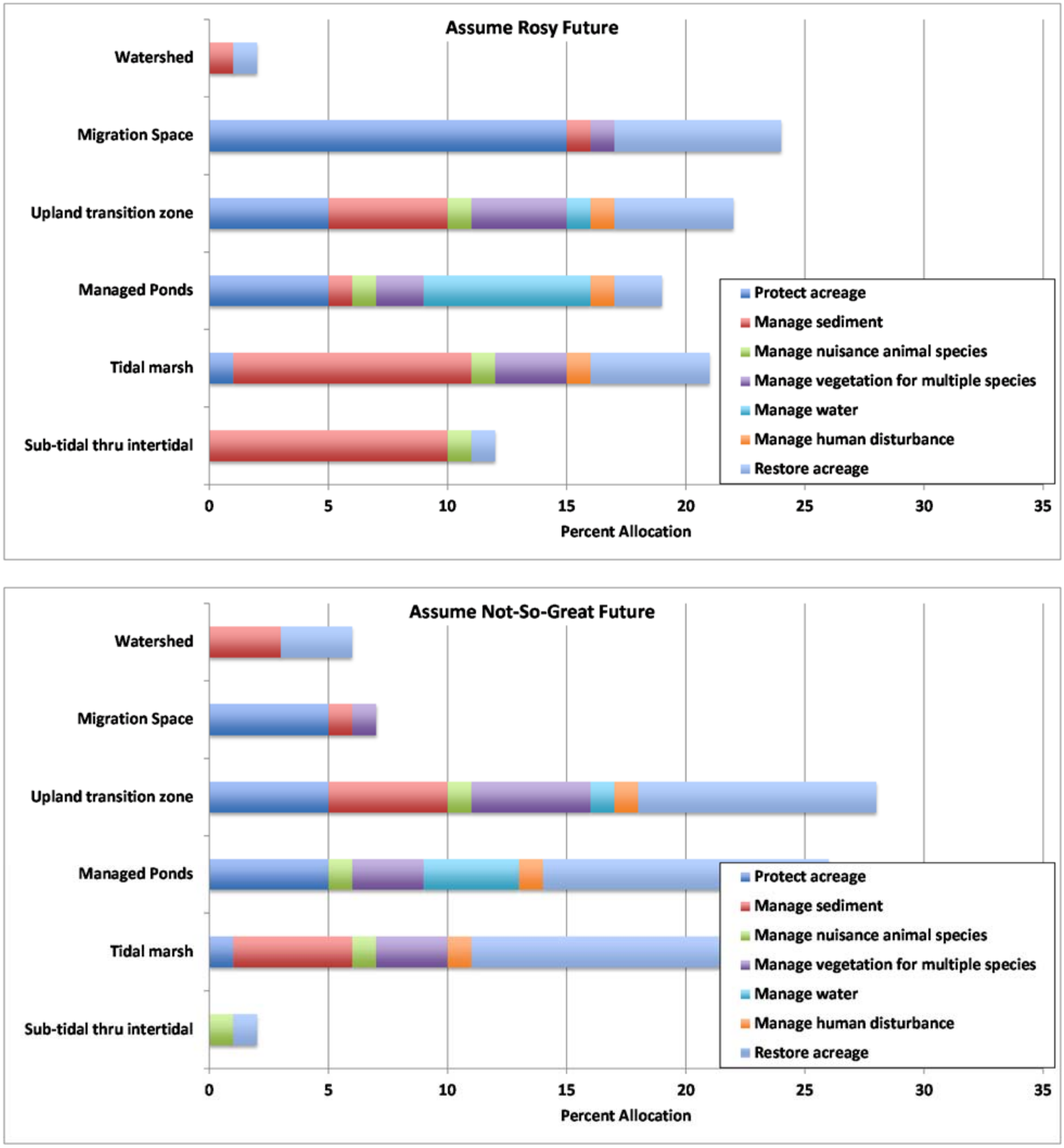

Figure 5.4.2. Longer-term allocation options for South Bay.

Percent allocations to action categories (color codes in legend) within each of 6 Bayland ecosystems (y-axis) during the longer-term (2030-2050) management horizon, under two alternate future scenarios (2030-2100) for South Bay. See Table 3.4.1 and Table 3.4.2 for descriptions of the future scenarios.

5.4.5 Making predictions about drivers and conservation outcomes

In the workshop breakout sessions, the South Bay team began carrying out 3 of the following 4 steps:

1) (Provided in plenary: Ecosystem-specific influence diagrams linking action categories and external drivers (e.g., extreme storms) to the conservation objectives, which could apply to any subregion.)

2) Refine ecosystem-specific influence diagram for the focal subregion showing how the conservation objectives are related to indicators, and in turn how indicators are affected by action categories and external drivers via intermediate drivers.

3) Choose measurable attributes and binary levels (e.g., stable/increasing vs. decreasing) for the indicators, intermediate drivers, and external drivers within the influence diagrams.

4) Assign probabilities to possible outcomes for the conservation objectives and how they are related to indicators, and in turn how indicators are related to external drivers and resource allocation, sometimes via intermediate drivers.

Step 1 was already completed and diagrams provided to stakeholders before the breakout sessions. The South Bay team carried out steps 2-4 in an iterative fashion starting during the workshop breakouts and completed through the subregional team meetings during and after the stakeholder workshop (see section 5.4.1).

Following a set of guidelines during workshop breakouts (see section 3.5.1), the South Bay team developed an influence diagram for each of the four estuarine ecosystems in the near-term and in the long-term (Appendix E-4), which were modified from influence diagrams provided during plenary (Figure 4.5.1). Each ecosystem-specific influence diagram showed linkages between indicators representing biotic integrity (overarching conservation objective), intermediate drivers, external drivers (i.e., beyond the control of South Bay conservation partners), and categories of actions (Table 3.3.1).

5.4.5.1 External drivers and intermediate drivers

Attributes and thresholds between binary levels for the indicators of the conservation objectives in South Bay were described in section 5.4.2. Here we describe the attributes and thresholds for each intermediate driver and each external driver that are linked directly or indirectly to the indicators in the influence diagrams (Appendix E-4).

External drivers affect estuarine ecosystems and are beyond the control of managers. The South Bay team adopted future scenarios for external environmental drivers as discussed in plenary (Table 3.4.1), and from these three external environmental drivers were identified for South Bay (

Table 5.4.7). Consistent with discussions during the workshop plenary (see sections 3.4.1 and 3.5.1), the South Bay team agreed that although sea-level rise is an important external driver in the near-term (2015-2029), there is little uncertainty about its trajectory and associated impacts on estuarine ecosystems during this earlier timeframe. As such sea-level rise was considered as a constant rather than as a source of uncertainty in the near-term portion of the decision tool. Sea-level rise was, however, included explicitly as an external driver for the expected outcomes of the allocation outcomes over the long-term (2030-2100). The team adopted the Rosy and Not-So-Great scenarios developed during plenary for resource availability (Table 3.4.2), and this was included as an external driver.

Intermediate drivers influence indicators and are themselves influenced by external drivers and/or actions. Team members recognized there are many intermediate drivers that could be included, but to ensure a concise decision tool they limited the influence diagrams to the intermediate drivers (Table 5.4.8) having the greatest uncertainty and greatest potential impacts on the fundamental objectives.

Table 5.4.7. External drivers for the South Bay decision tool.

For the South Bay decision tool, three external drivers were included in the near-term (2015-2029) and four in the long-term (2030-2100). Consistent with other subregions, sea-level rise was assumed constant during the near-term. Unless otherwise noted, these were classified to be consistent with the scenarios discussed during the workshop plenary (Table 3.4.1).

1) *Sea-level rise (long-term only)*
   - "Not-So-Great" sea level is 165 cm greater than 2014 level. "Rosy" sea level is 52 cm greater than 2014 level.

2) *Extreme weather events*
   - Frequency and intensity of droughts, storms, along with accompanying king tides.

5) *Temperature and precipitation patterns*
   - Normal = matching recent patterns vs. abnormal seasonality, magnitude, and amount of snowpack storage.

2) *Sediment supply*
   - Stable/increasing vs. decreasing. Unlike the other subregions, managers in South Bay do not have direct control over the amount of sediment entering their subregion

Table 5.4.8. Intermediate drivers for the South Bay decision tool.

Intermediate drivers are listed for each estuarine ecosystem of South Bay. Two additional intermediate drivers were included for the long-term (2030-2100) horizon to represent the likely possibility that tidal marsh, subtidal, and intertidal ecosystems will migrate landward with sea-level rise in the long-term depending on changes in availability of suitable upslope areas during the near-term (2015-2029). Each of these intermediate drivers was classified as either stable/increasing or decreasing during the respective time horizon.

Both near-term and long-term

1) *Subtidal and intertidal mudflats*: acreage of mudflats with high-quality bird food (i.e., invertebrates)
2) *Tidal marsh*: physical attributes including sediment accretion, channel morphology, and tidal exchange
3) *Managed ponds*: water quality
4) *Upland transition zone*: available acreage for protection

Long-term only

5) *Subtidal and intertidal mudflats*
    a. Total acreage of upland transition zone in the near-term
    b. Total acreage of tidal marsh in the near-term
6) *Tidal marsh*: Total acreage of upland transition zone in the near-term

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5.4.5.2 Eliciting quantitative inputs for decision tools

Working with a decision analyst and following a set of guidelines (Appendix G), the South Bay team went through an expert elicitation process to assign probabilities to outcomes for attributes represented in each ecosystem-specific influence diagram for each outcome horizon (Appendix E-4). The general methods used for the elicitation are described in section 3.5.3. The South Bay team went through two separate elicitation processes, one for attributes in the near-term and one for attributes related to the long-term outcome horizon.

5.4.6 Identifying & quantifying trade-offs

Following a set of guidelines (see section 3.6) and working with a decision analyst, South Bay team members provided utilities representing how they value possible outcomes in terms of changes in biotic integrity for the four estuarine ecosystems in the near-term (2015-2029) and in the long-term (2030-2100). South Bay stakeholders placed more value on tidal marsh than on other estuarine ecosystems for both outcome horizons, and ecosystem tradeoffs did not differ substantially between these time periods (Figure 5.4.3). There was, however, more disparity among stakeholders regarding long-term tradeoffs than their near-term tradeoffs. When comparing tradeoffs between outcome horizons, South Bay stakeholders were on average more averse to decreasing biotic integrity in the long-term than they were in the near-term for all ecosystems except subtidal and intertidal mudflats, where they were equally averse to decreasing biotic integrity for both time horizons (Figure 5.4.4). These utility values, combined with the elicited probabilities for attributes in the decision tool (see section 5.4.5.2), were used to compute expected performance of each allocation option in each management horizon.

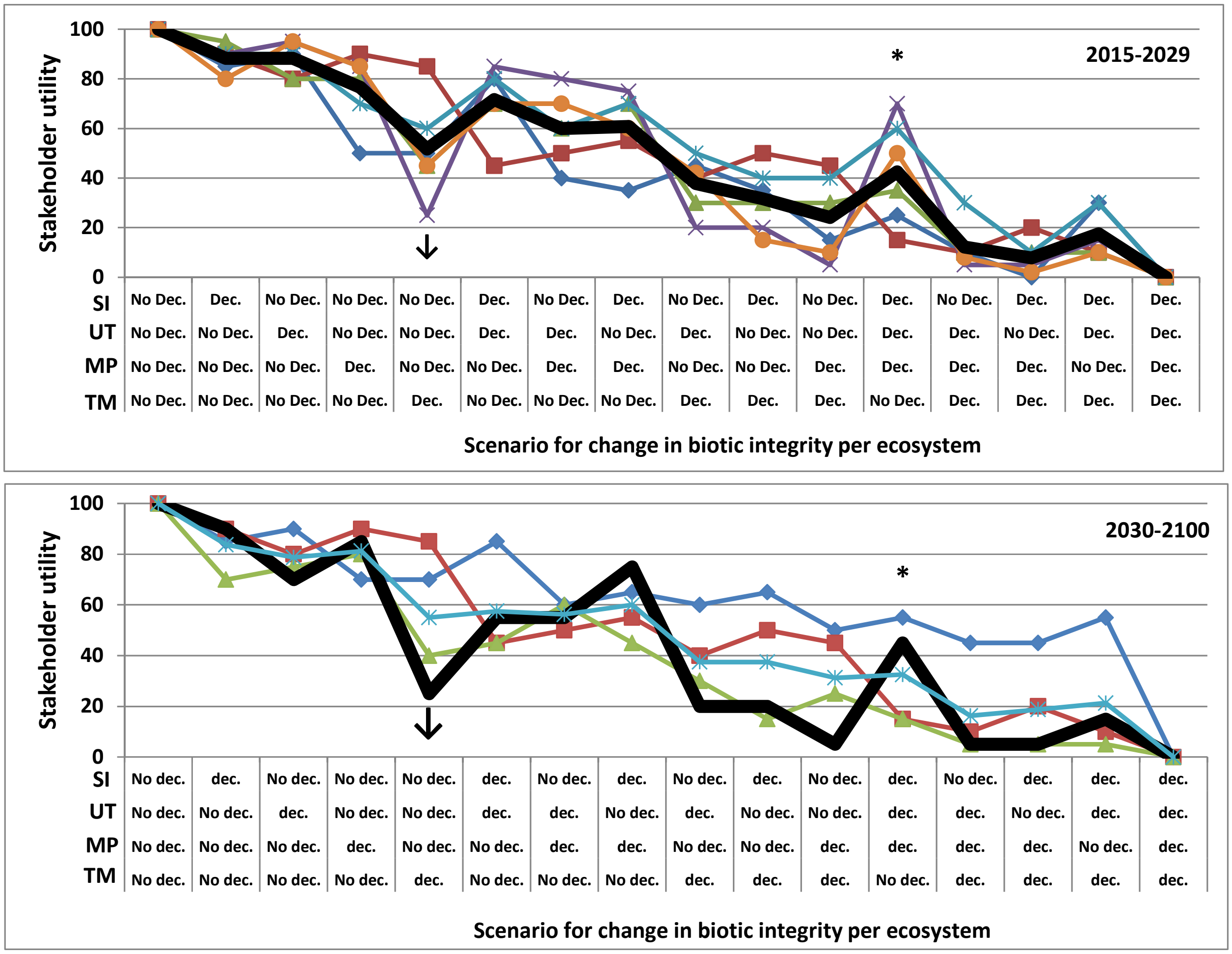
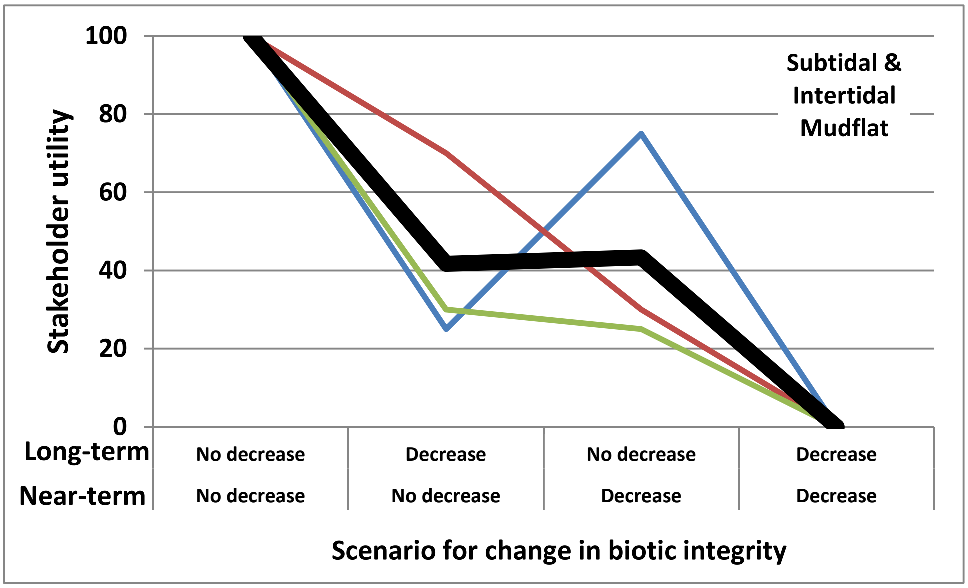


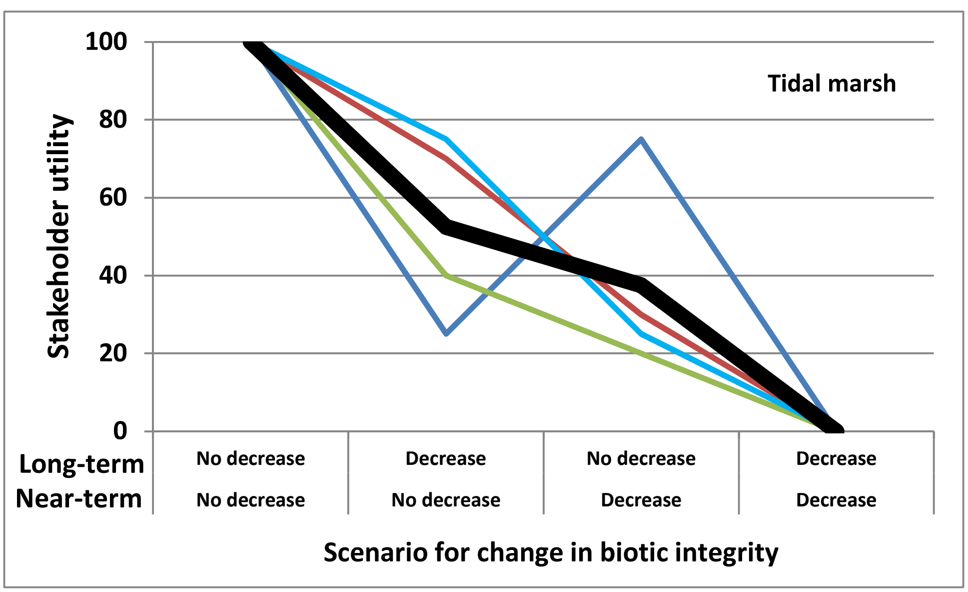
Figure 5.4.3. Stakeholder trade-offs among ecosystems in South Bay.

Tradeoffs were quantified based on an elicitation process, where stakeholders independently assigned a value (0-100) representing their preferences for possible changes in biotic integrity in each of the four focal estuarine ecosystems during the near-term (2015-2029) and long-term (2030-2100).Change in biotic integrity was defined by changes in particular biotic attributes (e.g., change in shorebird abundance) in each ecosystem. No dec. = stable or increasing; dec. = decreasing biotic integrity. SI=Subtidal and intertidal; UT = Upland transition; MP = Managed ponds; TM=Tidal marsh. Solid thick black line is the average utility value across stakeholders; colored lines represent utilities of individual stakeholders (n=6 for near-term; n=4 for long-term). Down arrow (↓) indicates scenario where biotic integrity is decreasing only in tidal marsh, and asterisk (*) indicates scenario where biotic integrity is decreasing in all ecosystems except tidal marsh. South Bay stakeholders on average valued changes in biotic integrity in tidal marsh more than in the other estuarine ecosystems.

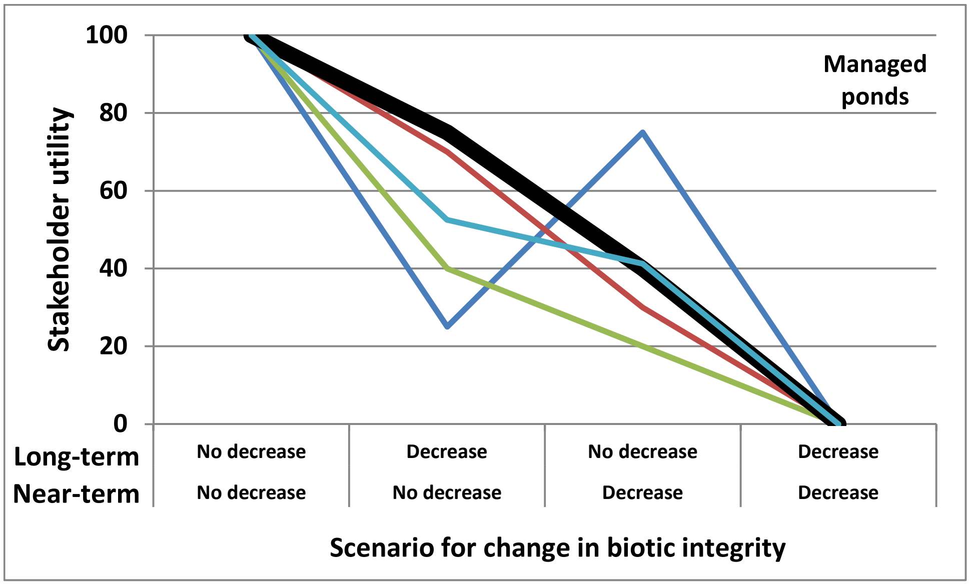
Figure 5.4.4. Stakeholder trade-offs between outcome horizons in South Bay.

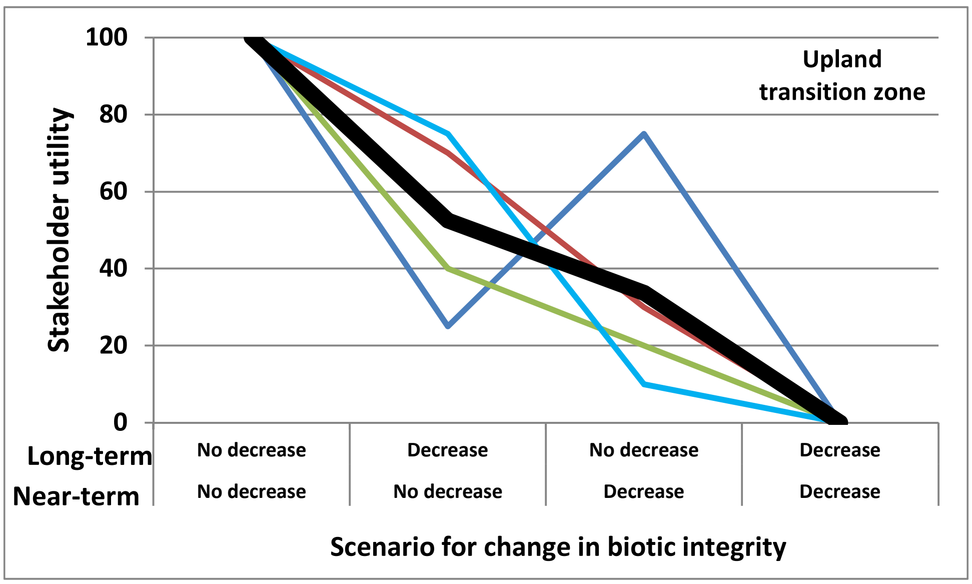
Tradeoffs were quantified based on an elicitation process, where stakeholders independently assigned a value (0-100) representing their preferences for possible changes in biotic integrity in each of the four focal estuarine ecosystems during the near-term (2015-2029) and long-term (2030-2100). Change in biotic integrity was defined by changes in particular biotic attributes (e.g., change in shorebird abundance) in each ecosystem. Solid thick black line is the average utility value across stakeholders; colored lines represent utilities of individual stakeholders (n=6 for near-term; n=4 for long-term). South Bay stakeholders were on average more averse to decreasing biotic integrity in the long-term than they were in the near-term for all ecosystems except subtidal and intertidal mudflats, where they were equally averse to decreasing biotic integrity for both time horizons.





Stakeholder trade-offs between outcome horizons in South Bay, continued.


100
80
60
40
20
0
Stakeholder utility
Managed ponds
Long-term
Near-term
No decrease
No decrease
Decrease
No decrease
No decrease
Decrease
Decrease
Decrease
Scenario for change in biotic integrity


100
80
60
40
20
0
Stakeholder utility
Upland transition zone
Long-term
Near-term
No decrease
No decrease
Decrease
No decrease
No decrease
Decrease
Decrease
Decrease
Scenario for change in biotic integrity

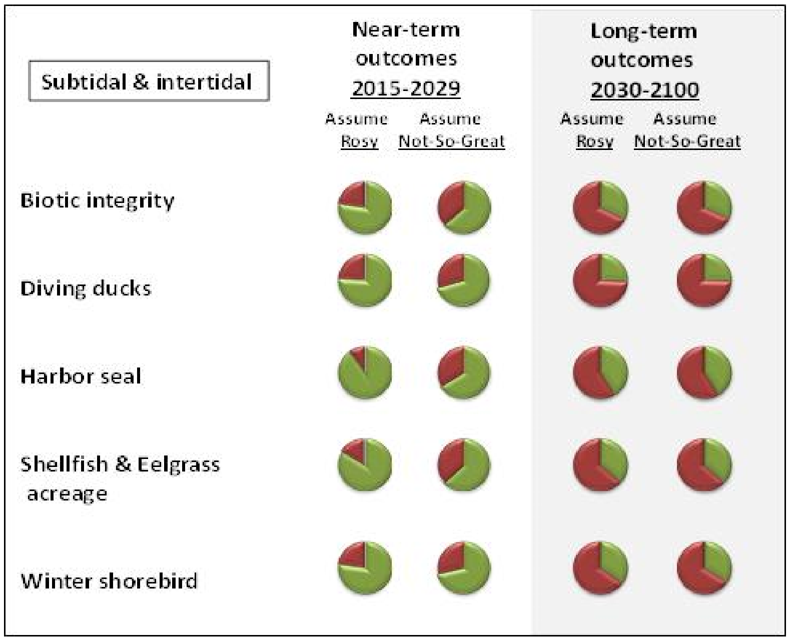
5.4.7 Identifying recommended allocations and main findings

Using the averaged probabilities and utilities from South Bay team members, the subregional decision tool (see section 3.7.1; Appendix I) indicated that the recommended option in the near-term (2015-2029) and in the longer-term (2030-2050) management horizon is to implement the assume-rosy allocation (Table 5.4.5 and Table 5.4.6; see also section 3.4.1). Under this baseline set of assumptions, we can expect 11% greater performance (in terms of tradeoffs among conservation objectives in the near-term and long-term; see section 3.6) by implementing the assume-rosy allocation (53% performance expected) than by implementing the assume-not-so-great allocation (42% performance expected). With the exception of change in acreage dominated by tall vegetation during the near-term in upland transition zone, predicted outcomes were more optimistic under the assume-rosy than under the assume not-so-great allocation (Figure 5.4.5). Predictions for biotic integrity in the long-term were roughly equivalent between the two resource allocation options. This can be explained by the small differences in near-term likelihoods of stable or increasing acreages of tidal marsh and of upland transition zone[15] between the two allocation options. Longer-term actions and drivers appear to be more important for achieving long-term conservation objectives.

[15] Near-term changes in acreage of tidal marsh and in acreage of upland transition zone were the only two near-term factors that were included as drivers of long-term factors (in particular, they were drivers of long-term changes in mudflat quality acreage and in tidal marsh acreage size/acreage/connectivity).

Figure 5.4.5. Predicted outcomes for biotic integrity in estuarine ecosystems of South Bay.

Predicted outcomes for biotic integrity of estuarine ecosystems of South Bay under two near-term (2015-2029) resource allocation options with contrasting assumptions resource availability and external environmental drivers from 2015 through 2100. The green area in each pie chart represents the probability that an attribute will be stable or increasing during the respective outcome horizon. Probabilities were averaged across independent inputs from 6 stakeholders for the near-term (2015-2029) and 4 stakeholders for the long-term (2030-2100) outcomes.



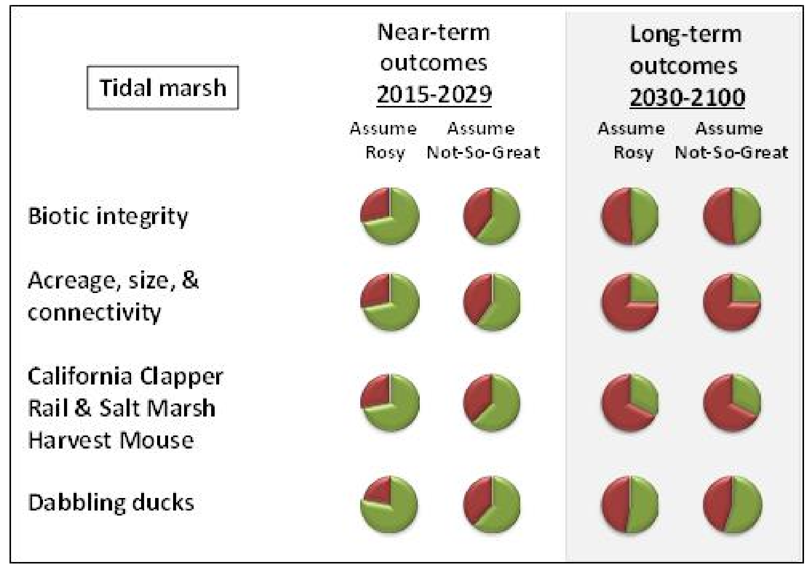
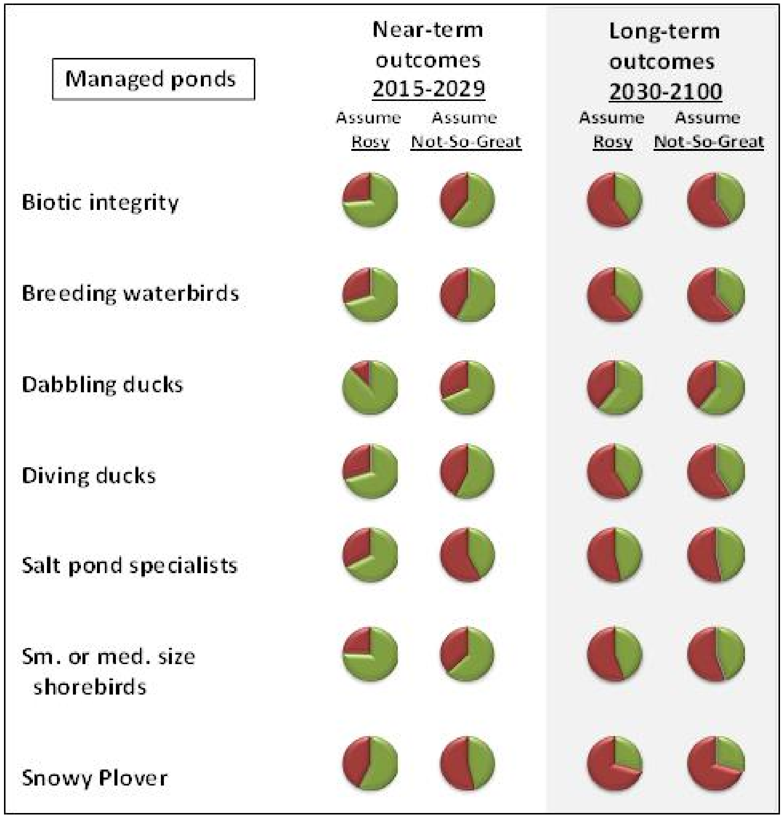
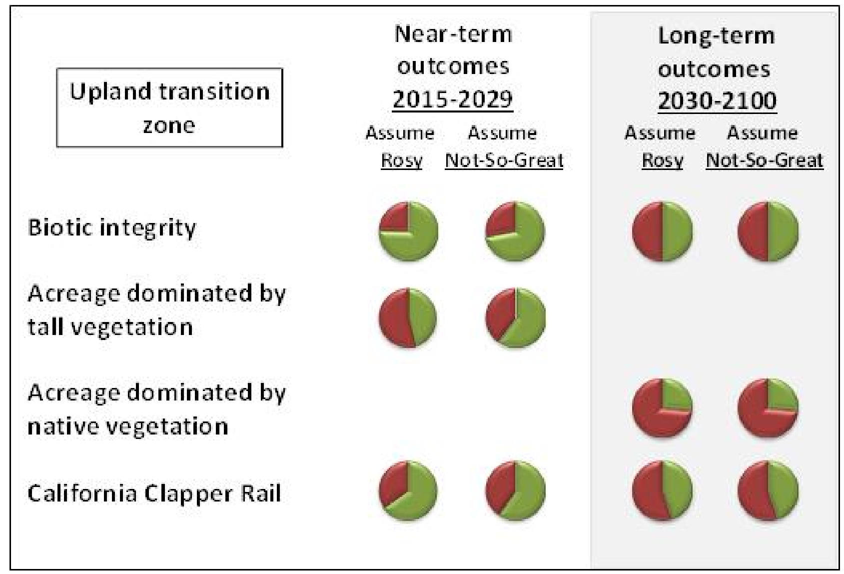
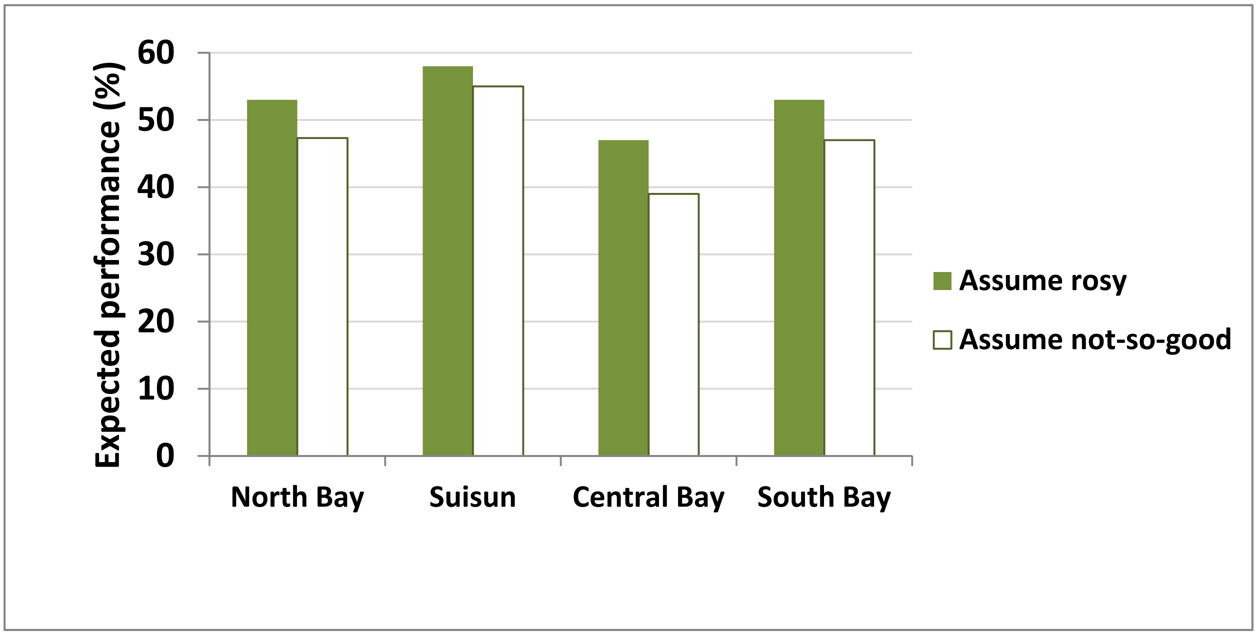


Figure 3.4.2. Predicted outcomes for estuarine ecosystems of South Bay (continued).





Expected performance (% chance of stable or increasing biotic integrity across ecosystems) of assume-rosy resource allocation by subregion



5.4.7.1 <u>Sensitivity analysis and value of resolving uncertainty</u>

The near-term (2015-2029) and longer-term (2030-2050) recommendations remained the assume-rosy allocation (Table 5.4.5 and Table 5.4.6) even when using pessimistic probabilities for external drivers (e.g., resource availability, extreme storms, rate of sea-level rise) in place of probabilities averaged across stakeholders[16]. That means, the recommendations are insensitive (i.e., robust) to uncertainties about the external drivers in the near-term (2015-2029) and long-term (2030-2100). The longer-term recommendation also remained the same when altering near-term changes in acreage of tidal marsh and of upland transition zone, the only near-term factors included as drivers of long-term factors (in particular, they were drivers of long-term changes in mudflat quality acreage and in tidal marsh acreage size/acreage/connectivity). The longer-term recommendation, then, was not dependent on changes in acreages for tidal marsh or for upland transition zone even though these near-term changes have at least some effect on the ability of the estuary to migrate upwards with sea-level rise in the long-term.

The recommendations did change when using optimistic probabilities for effects of the assume-not-so-great allocation on focal attributes (Table 5.4.9). Furthermore, there would be 8% expected gain in performance[17] (in terms of the tradeoffs in biotic integrity among the four estuarine ecosystems) if all focal near-term uncertainties are resolved through further research and analysis. Likewise, there is at most 5% expected gain in performance if all focal long-term uncertainties are resolved before the longer-term decision is made. Stakeholders in South Bay should consider whether they are willing to invest more in research and analysis to reach the maximum expected gains in performance. *Unless these uncertainties are resolved, our recommendation remains to carry out the assume-rosy allocations for both time horizons.*

[16] Sensitivity analysis entailed exploring differing sets of probabilities obtained from individual stakeholders using an independent elicitation process. See section 3.7.

[17] Expected gains in performance were based on a decision-analytic approach of calculating the expected value of perfect information (Runge et al. 2011). Expected gains shown in the table reach a maximum value depending on their levels of belief in the two sets of probabilities used in the sensitivity analysis. These levels of belief have yet to be elicited.

Table 5.4.9. Expected gains after resolving uncertainties for near-term in South Bay.

Highest expected gains in performance[2] after resolving uncertainties (formally: expected value of perfect information) about effectiveness of resource allocation options in focal estuarine ecosystems of South Bay for the near-term (2015-2029).

Focal ecosystem	Uncertainties[b] to be resolved about resource allocation effectiveness in the near-term (2015-2029)	Highest expected % gain in performance after resolving focal set of uncertainties
Subtidal and intertidal[a]	Mudflat quality acreage Shellfish and eelgrass acreage Winter shorebird abundance Diving duck abundance	2.3%
Tidal marsh	Acreage, size, and connectivity of tidal marsh Abundance of Ridgway's Rail and salt marsh harvest mouse	2.4%
Managed ponds	Breeding waterbird abundance Dabbling duck abundance Diving duck abundance Salt-pond specialist abundance Sm./med. shorebird abundance Snowy Plover abundance Water quality	1.5%

[a] When focusing on subtidal and intertidal ecosystems, the recommendation was only sensitive to uncertainty about resource allocation effectiveness when projections for external environmental drivers were pessimistic.
[b] Uncertainties about changes in each of the focal attributes.

Table 5.4.10. Expected gains after resolving uncertainties for long-term in South Bay.

Highest expected gains in performance[2] (aka expected value of perfect information) after resolving uncertainties about effectiveness of resource allocation options in focal estuarine ecosystems of South Bay in the long-term (2030-2100).

Focal ecosystem	Uncertainties to be resolved about resource allocation effectiveness in the near-term (2030-2100)	Highest expected % gain in performance after resolving focal set of uncertainties
Tidal marsh	Physical attributes of tidal marshes Acreage, size, and connectivity of tidal marsh Abundance of Ridgway's Rail and salt marsh harvest mouse Dabbling duck abundance	1.8%
Managed ponds	Breeding waterbird abundance Dabbling duck abundance Diving duck abundance Salt-pond specialist abundance Sm./med. shorebird abundance Snowy Plover abundance Water quality	0.9%
Upland transition zone	Acreage dominated by native plants Ridgway's Rail abundance	1.7%

Chapter 6. Comparison of subregional decision tools and recommendations

In Chapter 5, we presented decision tools that provided a recommended resource allocation for conservation of each subregion within SF Bay in the face of uncertainty about climate change and resource availability. Here, we compare each component of the subregional decision tools to give a sense for similarities and differences that emerged. This compare and contrast can help inform future efforts to expand on what we have learned through CADS Phase 1 to have an even more cohesive set of recommendations that aim toward a common set of conservation objectives and indicators of biotic integrity across the SF Bay Estuary.

6.1 Refining conservation objectives

Except for North Bay, all the subregional teams made an adjustment to the Bayland wide ecosystem classification to better suit their subregion (Table 6.1.1).

Table 6.1.1. Classifications of Bayland ecosystems for the subregional decision tools.

Ecosystem	North Bay	Suisun	Central Bay	South Bay
Sub-tidal and intertidal mudflat	X	X	X	X
Tidal marsh	X	X[a]	X	X
Diked baylands and managed ponds	X	X		X[b]
Upland transition zone	X	X[a]	X	X
Migration Space	X	X	X	X
Watershed	X	X	X	X

[a] The Suisun team merged tidal marsh and upland transition zone when developing their allocation options (see section 5.2.4).

[b] The South Bay team ignored managed wetlands other than managed ponds when developing their decision tool (see section 5.3.2).

For each ecosystem, the teams defined an overarching conservation objective that the biotic integrity of the ecosystem as a whole should be stable or increasing during the near-term (2015-2029) and long-term (2030-2100) outcome horizons. Indicators were then chosen to represent the most important desired outcomes for stakeholders in each ecosystem (Table 6.1.2). Birds were the most commonly chosen indicators, followed by plants, fish, and indicators that integrate disparate attributes of the ecosystem. Less frequently chosen as indicators were mammals, physical attributes, shellfish (alone), and herpetofauna (alone). Most often chosen bird guilds were ducks and shorebirds. When looking for commonalities in the categories of indicators chosen for each ecosystem, subtidal and intertidal mudflats had the most commonalities, followed by tidal marsh, managed wetlands, and upland transition zone. Selection of particular indicator species or ecosystem attributes varied widely among subregions for any given ecosystem. Only three indicators were chosen for multiple subregions: subtidal acreage with native living substrate, upland transition zone acreage dominated by native plants, and upland transition zone acreage with suitable wildlife refugia. When including the integrative indicators, there were multiple subregions that chose Ridgway's Rail, salt marsh harvest mouse, plant biomass, and invertebrate biomass.

In addition to indicators of biotic integrity, Central Bay and South Bay included an objective related to protection of human infrastructure (roads, buildings) from flooding. For South Bay, this was treated as a requirement and for Central Bay this was traded off against estuarine biotic integrity. Measures of flood protection, as with the indices of biotic integrity, could be scaled up to the regional level and traded off against estuarine biotic integrity.

Scaling up the indicators from the subregional level to the entire SF Bay Estuary (i.e., regional level) would require further conversations with the entire group of stakeholders, starting with the indicators chosen for CADS Phase 1. In Table 6.1.3, we propose 2-3 indicators for each of the four estuarine ecosystems that could scale up from subregions to the entire Estuary.

Table 6.1.2. Indicators of biotic integrity by ecosystem and subregion.

Indicators of biotic integrity chosen for inclusion in subregional decision models for each of four focal ecosystems in the SF Bay Estuary. A dot (●) indicates that the category of indicators was chosen by a subregion, and an X indicates a particular indicator was chosen within a category. Attribute of interest for all listed wildlife species was abundance unless otherwise noted.

Indicator	North Bay	Suisun	Central Bay	South Bay
Subtidal and intertidal mudflats				
Physical			●	
Total mudflat acreage			X	
Subtidal water quality			X	
Plants	●	●		
Eelgrass acreage	X			
Acreage dominated by natives		X		
Birds	●			●
Ducks				
Divers				X
Shorebirds				
Diversity and abundance	X			
Winter abundance				X
Mammals				●
Harbor seal				X
Shellfish acreage	●			
Fish	●	●	●	
Salmonids	X			
Forage fish biomass			X	
Delta smelt		X		
Integrative	●		●	●
Acreage of native living substrate			X	X
Plant and invertebrate biomass	X		X	

Indicators of biotic integrity by ecosystem and subregion, continued.

Indicator	North Bay	Suisun	Central Bay	South Bay
Tidal marsh				
Physical				●
1999 Bayland Goals criteria for marsh acreage, size, and connectivity are met				X
Plants	●			
Acreage dominated by natives	X			
Birds	●	●		●
Obligate tidal marsh species				
Diversity and abundance		X		
Ridgway’s Rail	X			
Ducks				▪
Dabblers				X
Mammals	●	●		
Native small-bodied diversity and abundance		X		
Salt marsh harvest mouse	X			
Fish	●			
Diversity and abundance	X			
Integrative			●	●
Recovery criteria met			X	
Total plant and invertebrate biomass			X	
Ridgway's Rail & salt marsh harvest mouse				X

Indicators of biotic integrity by ecosystem and subregion, continued.

Indicator	North Bay	Suisun	Central Bay[a]	South Bay[b]
Managed wetlands				
Birds	●	●		●
Breeding waterbird				X
Salt-pond specialists				X
Ducks	▪	▪		▪
Richness and density	X			
Winter abundance		X		
Divers				X
Shorebirds	▪			▪
Diversity and abundance	X			
Small- to medium-size abundance				X
Snowy Plover				X
Mammals		●		
Salt marsh harvest mouse		X		
Fish	●			
Diversity and abundance	X[c]			
Upland transition zone				
Plants	●	●		●
Eelgrass acreage				
Acreage dominated by natives	X	X		X[d]
Total biomass				
Acres with suitable wildlife refugia	X			X[d]
Birds	●			●
Ridgway's Rail				X
Song Sparrow and Common Yellowthroat	X			
Reptile and amphibian abundance	●			
Integrative			●	
Recovery criteria met			X	

[a] Central Bay ignored managed wetlands due to their small acreage in this subregion.

[b] Only managed ponds were considered for South Bay.

[c] Abundance of native fish for near-term, and density of native fish per wetland for long-term in North Bay.

[d] Acreage with suitable refugia for near-term, and acreage dominated by natives for long-term in South Bay upland transition zone.

Table 6.1.3. Proposed indicators that scale up to SF Bay Estuary.

Proposed indicators of biotic integrity for each ecosystem that can scale up from subregions to the entire SF Bay Estuary, based on indicators chosen by subregional groups in CADS Phase 1.

Subtidal and intertidal mudflats

- Stable or increasing acreage with native living substrate
- Stable or increasing native fish diversity and abundance
- Stable or increasing shorebird diversity and abundance

Tidal marsh

- Criteria for endangered species in the tidal marsh recovery plan are met
- Stable or increasing acreage dominated by native plants

Managed wetlands

- Stable or increasing diversity and abundance of ducks
- Stable or increasing diversity and abundance of shorebirds

Upland transition zone

- Criteria for endangered species in the tidal marsh recovery plan are met
- Stable or increasing acreage dominated by native plants

6.2 Refining action categories

The original classification (Table 3.3.1) included two action categories related to managing water, which we now realize was unnecessary splitting of managing water quality and water quantity. These are often managed simultaneously, and so all the subregional teams used a single action category for managing water. The original "Manage individual wildlife species" category was intended to include both vertebrates and invertebrates, and the Suisun team made special note that some of their actions in this category apply to invertebrate species.

With some other small exceptions, all of the teams adopted the original action categories. The most significant change was in South Bay, where the team added an action category called "Restore acreage". This added category represents expenditures on capital costs for infrastructure and staffing needed to conduct a restoration project, distinguishing this from other action categories representing annual expenditures on operations and maintenance of (multi-year) restoration projects. South Bay also narrowed the original action category of "Manage individual wildlife species" to only focus on nuisance wildlife species such as feral cats. For South Bay, then, they did not include actions toward individual desirable wildlife species such as translocation or construction of floating islands for Ridgway's Rail. Another minor change was that Suisun added an action category for collecting information, to be explicit that some funds would be allocated to research and monitoring to inform adaptive management within the near-term.

Lastly, some subregional teams chose to focus on taking action in a subset of the Bayland ecosystems. South Bay ignored diked wetlands and instead just focused on actions within managed ponds rather than on managed wetlands in general, because of the small amount of diked areas in that subregion. Central Bay ignored managed wetlands entirely, because they take up an insignificant amount of area in that subregion.

6.3 Developing resource allocation options

Subregions differed in how they allocated resources among the Bayland ecosystems, which reflected the geographic variation in the constraints and opportunities for taking conservation action (Figure 6.3.1). When pooling allocations by ecosystem, the ecosystem-specific percentages did not differ substantially between allocation options for a given subregion. Most of the resources were allocated to tidal marsh and managed wetland, followed by migration space, subtidal and intertidal mudflats, and watershed. When comparing action categories, most resources were allocated toward protecting acreage and managing sediment.

Because of the differing ways they defined their allocation options, comparing subregions in how they allocated percentages among action categories presents challenges. The best comparison is for tidal marsh (Figure 6.3.2), where we can see that North Bay and Central Bay differed substantially in how they allocated resources among action categories. Whereas the North Bay team allocated no resources toward managing water and distributed resources quite evenly among the remaining categories, Central Bay allocated most resources toward managing sediment and individual wildlife species with smaller percentages toward the remaining categories. Furthermore, allocations among action categories were identical between options within tidal marsh of Central Bay. The North Bay allocations were quite similar, but resources were shifted from managing sediment to managing vegetation under the more pessimistic allocation option.

Table 6.3.1. Dominant allocation percentages by action category, subregion, and time horizon.

Action categories receiving the most resource allocation for each of two management time horizons in each of four subregions within SF Bay. X = more allocated than expected by chance among the action categories; XX = more than double the amount expected by chance was allocated.

Subregion	Management horizon	Protect acreage	Manage sediment	Manage individual wildlife	Manage vegetation	Manage water	Manage human disturbance
North Bay	2015-2029	XX	X				
	2030-2050	X	X				X
Suisun[a,b]	2015-2029	X			X	X	
	2030-2050	XX				X	
Central Bay[a]	2015-2029	XX	X				
	2030-2050	X	X	X			
South Bay[c]	2015-2029		(X)		(X)	(X)	
	2030-2050	X	X		(X)	(X)	

[a] Longer-term (2030-2050) allocation options were not analyzed for Suisun or Central Bay.

[b] There was an additional category "collect information"for Suisun, but it did not receive a large percentage allocation and is not shown for simplicity.

[c] There was an additional action category in South Bay called "restore acreage", which represented principal resources directed toward the establishment of long-term restoration projects such as staff and equipment. The "manage ___" action categories, then, represented annual expenditures to maintain the long-term restoration projects. The (X) symbols represent the large amount allocated to this added category for both time horizons.

Table 6.3.2. Dominant allocation percentages by ecosystem, subregion, and time horizon.

Bayland ecosystems receiving the most resource allocation for each of two management time horizons in each of four subregions within SF Bay. X = more allocated than expected by chance among the ecosystems.

Subregion	Management horizon	Subtidal & intertidal	Tidal marsh	Managed wetlands	Upland transition zone	Migration Space	Water-shed
North Bay	2015-2029			X	X	X	
	2030-2050			X	X	X	
Suisun[a,b]	2015-2029		(X)	X	(X)		
	2030-2050		(X)	X	(X)		
Central Bay[a,c]	2015-2029		X	na	X		
	2030-2050	X	X	na	X		
South Bay[d]	2015-2029		X	X	X		
	2030-2050		X	X	X	X	

[a] Longer-term (2030-2050) allocation options were not analyzed for Suisun or Central Bay.

[b] The Suisun team considered tidal marsh and upland transition zone as a single ecosystem when assigning allocation percentages, and the (X) symbol represents the large amount allocated to this merged ecosystem in both management time horizons.

[c] Managed wetlands were ignored in Central Bay due to their scarcity in this subregion.

[d] Diked marshes were ignored within South Bay, and only managed ponds were considered within the managed wetlands ecosystem classification.

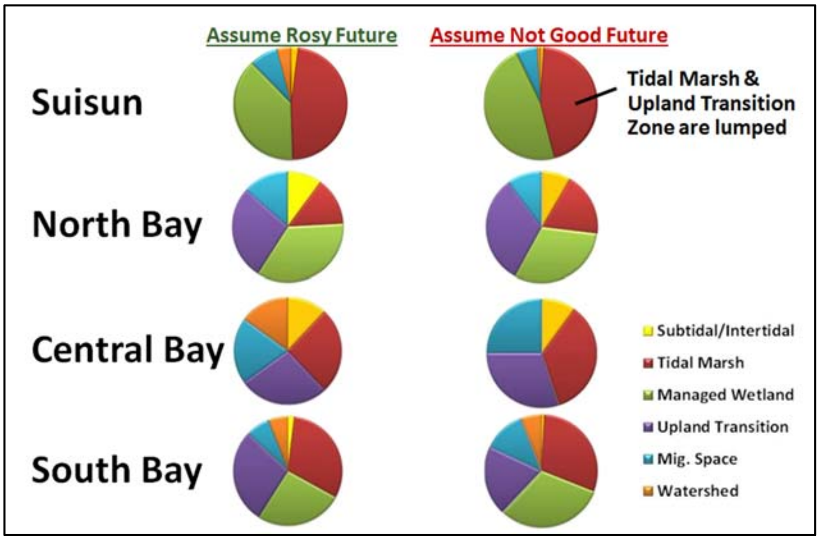


Figure 6.3.1. Subregional allocation options by ecosystem for the near-term.

Comparison of near-term (2015-2029) allocation options among subregions. For Suisun, tidal marsh and upland transition zone allocations are lumped and cannot be distinguished. Central Bay ignored managed wetlands.

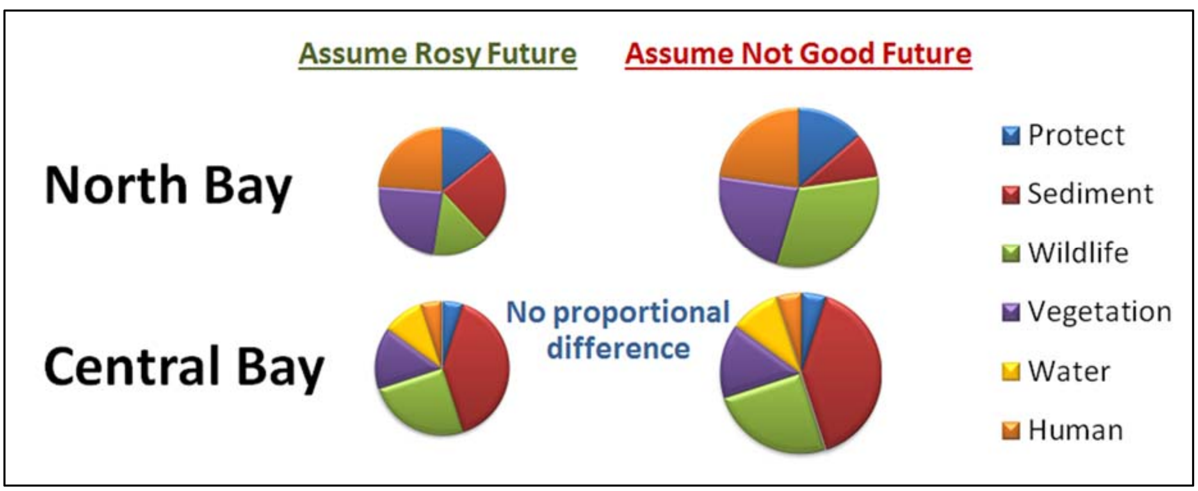


Figure 6.3.2. Subregional allocation options by action category for tidal marsh.

Comparison of near-term (2015-2029) allocation options for tidal marsh in North Bay and Central Bay. For Suisun, tidal marsh and upland transition zone allocations are lumped and cannot be distinguished. Because of the way they defined their action categories (see section 6.2 above), we cannot directly compare allocation options at the level of action category between South Bay and the remaining three subregions. The size of the pie circles are proportional to the percentage being allocated to tidal marsh under each option for each subregion. Action categories included: protect acreage, manage sediment, manage individual wildlife species, manage vegetation for multiple species, manage water, and manage human disturbance.

6.4 Making predictions about drivers and conservation outcomes

6.4.1 External drivers

External drivers affect estuarine ecosystems and are beyond the control of managers. For making predictions about outcomes of the conservation objectives, all the subregional groups adopted common scenarios for future changes in external drivers that were discussed as a larger group (e.g., extreme storms, sea-level rise, resource availability) (Table 3.4.1 and Table 3.4.2). All of the subregions included extreme weather events as drivers for each focal estuarine ecosystem in their decision tools (Table 6.4.1).

With the exception of Suisun, all teams included weather patterns as a source of uncertainty. Whereas North Bay and South Bay focused on uncertainty about air temperature and precipitation, Central Bay focused on uncertainty about water temperature in addition to air temperature. With regard to weather pattern uncertainty South Bay included this only for managed ponds, Central Bay included it only for subtidal and intertidal mudflats, whereas North Bay included this uncertainty in all four ecosystems.

Some teams were unique in their choice of external environmental drivers. In contrast with the other subregions where sediment is under at least partial control of managers, in South Bay sediment supply is outside their control and was included as an external driver because of its great importance and uncertainty. For the teams that completed the long-term portion of their decision tools (North Bay and South Bay), they both included uncertainty about the rate of sea-level rise during the long-term (2030-2100). North Bay was unique in that they included uncertainty about sea-level rise impacts during the near-term (2015-2029).

Table 6.4.1. External environmental drivers by subregion.

Uncertainties about external environmental drivers accounted for in subregional decision tools. Suisun and Central Bay did not complete the long-term portion of their decision tools.

	Near-term (2015-2029)				Long-term (2015-2029)	
Uncertainty about external environmental driver	North Bay	Suisun	Central Bay	South Bay	North Bay	South Bay
Extreme weather events	X		X		X	
Extreme storms		X		X		X
Drought		X				
Weather patterns						
Air temperature and precipitation	X			X	X	X
Air and water temperature			X			
Sediment supply				X		X
Sea-level rise impacts	X					
Sea-level rise amount					X	X

6.4.2 Intermediate drivers

Intermediate drivers influence conservation objectives and are themselves influenced by external drivers and/or actions. Team members recognized there are many intermediate drivers that could be included, but to ensure concise decision tools they only included drivers having the greatest uncertainty and greatest potential impacts on the conservation objectives. There was great variation among subregional decision tools with respect to which intermediate drivers were included (Table 5.1.7, Table 5.2.8, Table 5.3.7, and Table 5.4.8). This is not surprising, given the additional variation among subregions with respect to the indicators of biotic integrity. Each indicator has its own associated uncertainty as to how it links with action categories and external drivers. Despite the variation, most subregional teams included either explicitly or implicitly uncertainties about effects of management actions on physical dynamics (hydrology and sediment) and on biological dynamics in the case of actions to control or remove nuisance species. Although it would be ideal to have a common set of intermediate drivers among subregions, we believe these should be selected to fit the indicators and uncertainties for each subregion. Scaling up from the subregional level to regional level may not necessitate having intermediate drivers at that scale, as we would only need to roll up the subregional-scale indicators into corresponding regional-level indicators.

6.5 Identifying & quantifying trade-offs

When quantifying tradeoffs between ecosystems from the perspectives of stakeholders, we found that tidal marsh had a consistently high level of importance in all subregions (Figure 6.5.1). Relative importance of the remaining three estuarine ecosystems varied among subregions. For North Bay and South Bay stakeholders (who completed the long-term portion of their decision tools), the long-term (2030-2100) outcomes were more important than those in the near-term (2015-2029). As mentioned above (see section 6.1), when scaling up the CADS effort to the regional level there could be tradeoffs among ecosystems at that level and tradeoffs between subregional- and regional-scale conservation objectives.

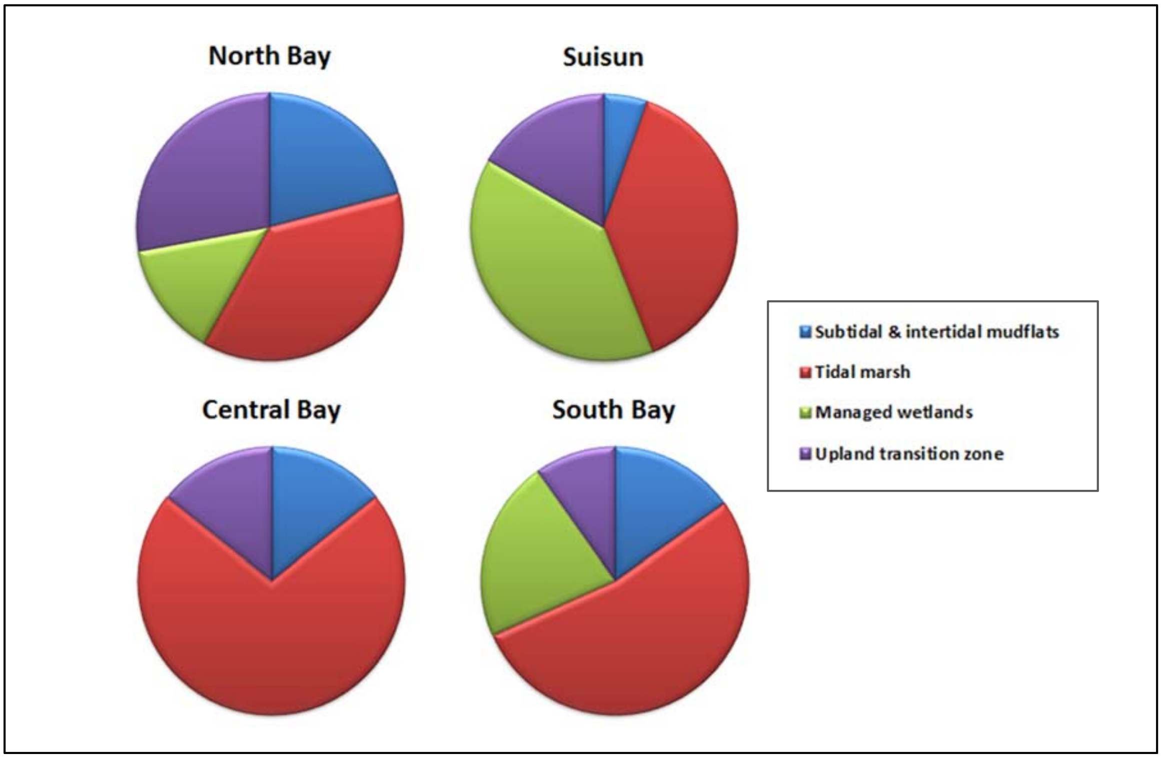


Figure 6.5.1. Relative importance of estuarine ecosystems by subregion in the near-term.

Relative importance of stable or increasing biotic integrity during the near-term (2015-2029) in four estuarine ecosystems from the perspectives of stakeholders working in four subregions of SF Bay. Central Bay ignored managed wetlands because of their scarcity in this subregion, and South Bay only considered managed ponds and ignored diked marshes to keep their decision tool tractable. Subregions consistently valued tidal marsh more than the other estuarine ecosystems.

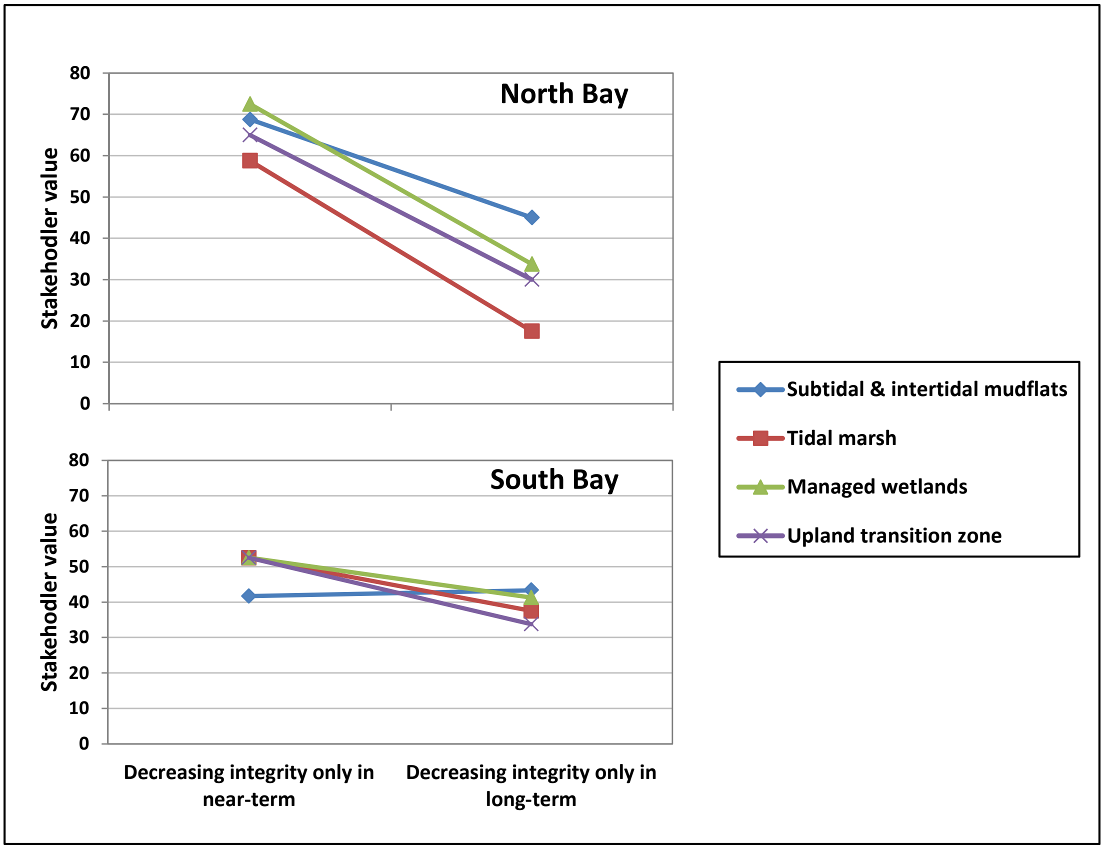


Figure 6.5.2. Tradeoffs between outcome horizons by ecosystem in North Bay and South Bay.

Stakeholders independently provided utility values for both combinations of possible changes in biotic integrity for the two outcome horizons (near-term = 2015 through 2029; long-term = 2030 through 2100) separately for each of four estuarine ecosystems. Stakeholders were on average more averse to decreasing biotic integrity in the long-term than they were in the near-term, especially in North Bay.

6.6 Identifying recommended allocations and main findings

In all subregions, the recommendation was to allocate resources in a way that assumes a rosy future for external environmental conditions (including climate and extreme storms) and for availability of resources. In layman's terms:

Even though we are unsure what will happen in the future with climate change and resource availability (from the best available science), we should plan as if there will be an increase in resources and that the climate won't end up in a worse-case scenario, even if it doesn't pan out that way.

This recommendation was surprising to some stakeholders, who would have thought that a more conservative approach should be taken to conservation in the Baylands. Intuitively, we should try to do everything we can to prepare for the worst possible scenarios for external drivers including climate change and availability of sediment and resources (funding, staff, equipment). This intuitive reasoning was not supported by the results from CADS, however. Instead, stakeholders were on average more optimistic about the effectiveness of an allocation option that assumes a rosy future even if the future turns out to be not so great for the external drivers. In other words, stakeholders believed the assume-rosy allocation to be robust to worse-case scenarios for the external drivers.

Recognizing the varied indicators chosen to represent biotic integrity among subregions (Table 6.1.2) and the varied membership of the subregional groups themselves (Table 2.2.3), we can compare predicted changes in biotic integrity among subregions (Figure- 6.1). South Bay had the most optimistic predictions for biotic integrity across ecosystems, and Suisun also had greater than 50% chance of stable or increasing biotic integrity in every estuarine ecosystem except subtidal and intertidal mudflats. Except for managed wetlands, North Bay and Central Bay predicted a less than 50% chance that biotic integrity would be increasing in each ecosystem. Across the board, there was substantial uncertainty about the projected trajectory of biotic integrity; the ecosystem-by-subregion probabilities of stable or increasing biotic integrity were all between 20 and 80%.

We found some variation among subregions with regard to expected conservation performance of the two allocation options (Figure- 6.2). Expected performance[18] ranged from 47-58% among subregions when implementing the assume-rosy-future allocation and 39-55% when implementing the assume-not-so-great-future allocation. Predicted outcomes were equally or more optimistic under the assume-rosy than under the assume not-so-great allocation, except for change in salt marsh harvest mouse capture efficiency in managed wetlands (Suisun), changes in mudflat acreage and in acreage dominated by living substrate (Central Bay), and change in acreage dominated by tall vegetation during the near-term in upland transition zone (South Bay).

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[18] Expected performance was measured in terms of the values stakeholders placed toward tradeoffs among ecosystems and, in the case of North Bay and South Bay, between the near-term and long-term outcomes. Tradeoffs were quantified in terms of possible changes in biotic integrity in the focal estuary ecosystems (see section 3.6).

The recommendations were all robust to uncertainties about external environmental drivers (e.g., extreme storms) and resource availability, meaning that the recommendation remained assume-rosy allocation regardless of assumptions about these drivers. Uncertainty about effectiveness of the allocation options did affect the recommendation, but the highest expected gain in performance after resolving this source of uncertainty in each subregion ranged from 4% in Suisun to 8% in Central Bay and South Bay. In almost every subregion, expected performance would be increased after resolving uncertainty about effectiveness of the allocation options for tidal marsh indicators (Table 6.6.1). There was no single indicator or subset of indicators within tidal marsh whose uncertainty was consistently important for the recommendation, however. It stands to reason that tidal marsh is a recommended ecosystem to consider doing further research and analysis to improve the performance of conservation efforts in the SF Bay Estuary, given its consistent importance for stakeholders around the Bay and high degree of uncertainty about how the conservation objectives are related to action categories.

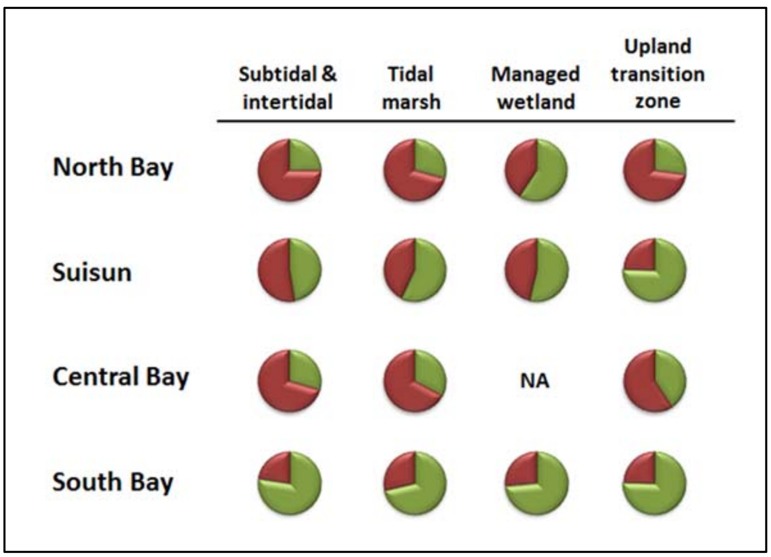

Figure- 6.1. Predicted changes in biotic integrity by ecosystem and subregion.

The green area toward upper right of each circle represents the probability of stable or increasing biotic integrity for the respective estuarine ecosystem. Central Bay did not consider managed wetlands, and South Bay only considered managed ponds within the managed wetlands class.

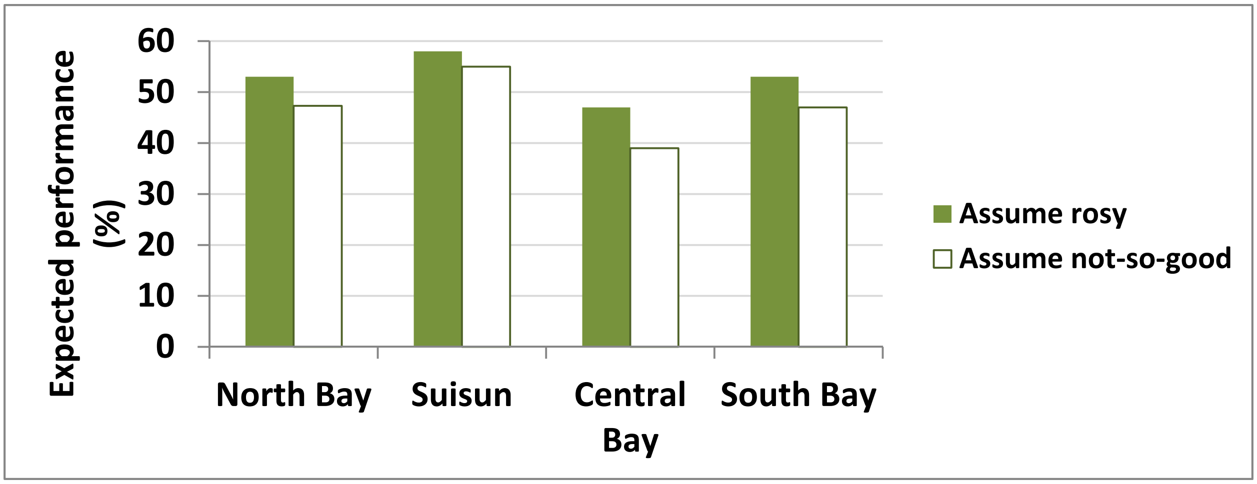

Figure- 6.2. Expected performance of allocation options by subregion.

Expected performance is based on tradeoffs between ecosystems and, for North Bay and South Bay, tradeoffs between near-term (2015-2029) and long-term (2030-2100) outcome horizons. For all subregions except Central Bay, expected performance would be 100% if biotic integrity is predicted to be stable or increasing in each of the focal estuarine ecosystems. In Central Bay, all ecosystems would need to have increasing biotic integrity and flood protection dollars would need to increase.

Table 6.6.1. Recommendations for further research on management effectiveness.

Indicators of biotic integrity and intermediate drivers (indicated with asterisk, *), listed by subregion and estuarine ecosystem. Resolving uncertainties about how these factors respond to the respective subregional resource allocation options could alter the management recommendation and lead to improved conservation performance.

Indicator	North Bay	Suisun	Central Bay	South Bay
Subtidal and intertidal mudflats				
Physical			●	
Total mudflat acreage			X	
Subtidal water quality			X	
Birds				●
Ducks				
Divers				X
Shorebirds				
Winter abundance				X
Fish			●	
Forage fish biomass			X	
Integrative			●	●
Acreage of native living substrate			X	X
Plant and invertebrate biomass			X	
Tidal marsh				
Physical		●		●
1999 Bayland Goals criteria for marsh acreage, size, and connectivity are met				X
*Water inundation regime		X		
Plants	●			
Acreage dominated by natives	X			
Birds	●	●		●
Obligate tidal marsh species				
Diversity and abundance		X		
Ridgeway’s Rail	X			
Ducks				
Dabblers				X
Mammals	●	●		
Native small-bodied diversity and abundance		X		
Salt marsh harvest mouse	X			
Fish	●			
Diversity and abundance	X			
Integrative			●	●
Recovery criteria met			X	
Total plant and invertebrate biomass			X	
Ridgeway's Rail & salt marsh harvest mouse				X

Recommendations for further research on management effectiveness, continued.

Indicator	North Bay	Suisun	Central Bay[a]	South Bay[b]
Managed wetlands				
Physical		●		
*Water inundation regime		X		
Birds		●		●
Breeding waterbird				X
Salt-pond specialists				X
Ducks				
Winter abundance		X		
Divers				X
Shorebirds				
Small- to medium-size abundance				X
Snowy Plover				X
Mammals		●		
Salt marsh harvest mouse		X		
Upland transition zone				
Plants	●			
Acreage dominated by natives	X			
Acres with suitable wildlife refugia	X			
Birds	●			
Song Sparrow and Common Yellowthroat	X			
Reptile and amphibian abundance	●			

[a] Central Bay ignored managed wetlands due to their small acreage in this subregion.

[b] Only managed ponds were considered for South Bay.

Chapter 7. Lessons learned from CADS process

For the first time, stakeholders engaged in resource management of SF Bay have collaboratively arrived at a set of conservation objectives that were explicitly used to inform optimal allocation of resources among ecosystems and action categories for each of the four subregions. These resource allocation recommendations build upon many years of conservation planning and habitat delivery in the region, which have provided essential ingredients including conservation objectives, management options at from segment to regional scales, monitoring and scientific information, and predictive models about the effects of management actions and external environmental drivers on estuarine ecosystems. The added value of CADS Phase 1 has been to bring all these ingredients together in a transparent, collaborative decision-analytic framework to develop recommendations for allocating limited conservation resources at subregional scale. This was the first time that such a comprehensive undertaking had been completed to address resource allocation at a subregional scale across multiple ecosystems and species in the SF Bay Estuary. Despite the complexity of the decision process, participants hung in there as they saw the value in this type of planning and decision-making, and many had not yet been exposed to an analytical framework upon which to base and measure their conservation decisions and actions.

This collaborative decision-analytic approach provided a platform for collaboration and laying out uncertainties and assumptions about linkages between actions and outcomes in a transparent fashion that had been called for by stakeholders. Traditional modes of implementing conservation actions in SF Bay (and elsewhere) have been focused on individual projects that addressed collective habitat conservation goals, but most are rarely planned and managed at the scale of an entire subregion. One of the most significant values of the CADS process has been bringing stakeholders from each of the geographic subregions together to collectively identify their conservation objectives and lay out their assumptions. Due to its level of rigor, CADS Phase 1 did require significant time investment from a subset of stakeholders in each subregion. We propose this kind of investment is essential to reach a vision of conserving ecosystems of SF Bay over the next decades and century.

A particular strength of CADS was engaging a broad suite of stakeholders throughout the process of developing conservation objectives, indicators of biotic integrity, action categories, allocation options, and recommendations. It is these individuals who can interpret and implement the recommended allocations in the subregions and ecosystems where they work. CADS Phase 1 was carried out on a very modest budget considering the broad scope, depth and complexity of the problem that was addressed, which has demonstrated that such an ambitious project can accomplished without a large financial investment. The project brought together a representative set of stakeholders and made them more cognizant that resource allocations should account for future uncertainties and that the allocations differ among subregions.

There have already been examples of how CADS Phase 1 is influencing conservation planning in SF Bay. It has precipitated managers thinking ahead about decisions they are making and in particular how they can allocate resources differently toward the identified conservation objectives under contrasting scenarios for the future regarding climate change and resource availability. For example, one stakeholder began to question some of the decisions for upland transitional habitats and tidal marsh migration in the North Bay. They realized that some of their concerns may not have been addressed in the BEHGU, which resulted in a discussion to ensure that her questions and concerns were incorporated into the BEHGU before it is finalized. As a result BEHGU authors have gone back and reviewed their work and checked to be sure these concerns were addressed, and several partners completed their calculations of the amount of available upland transitional habitat in their project areas.

In addition to providing explicit and quantitative recommendations for allocating resources, CADS Phase 1 also resulted in several intermediate products that were each developed in collaboration with stakeholders and were critical to arriving at the recommendations in a transparent fashion. First, there was a clear description of the decision to be addressed in a consistent manner for each subregion (see section 3.1). Second, Bayland ecosystems were clearly classified (Table 3.1.2). Third, conservation objectives and measurable attributes for them were clearly defined for each subregion (see section 6.1). Fourth, on-ground actions as recommended by the draft BEHGU were combined into categories to provide a consistent basis for resource allocation within Bayland ecosystems in each subregion (Table 3.3.1). Fifth, future scenarios for external environmental drivers and for resource availability were developed such that they would apply to all subregions (see section 3.4.1). Sixth and finally, for each subregion ecosystem-specific influence diagrams linking action categories and external drivers to conservation objectives via intermediate drivers were developed (Appendix E). These influence diagrams integrate all of the previously listed intermediate products and by themselves represent a novel and significant achievement of CADS Phase 1.

Successes and challenges encountered during the project were in general alignment with those experienced in other broad-extent conservation efforts (Beever et al. 2015), and in this chapter we synthesize these as lessons learned to inform future conservation planning efforts within and beyond SF Bay. In this chapter we review the steps of the project (Chapter 2) to point out particular areas where SF Bay provides unique opportunities for harnessing a multitude of conservation partners with a common vision, capacity, and momentum for overcoming challenges to coordinate and adapt in the face of uncertainty to conserve estuarine ecosystems of SF Bay.

In the sections that follow, we summarize the lessons learned during each step of the CADS project.

7.1 Refining decision frame and project design

The decision frame was broad in scope and in depth: developing a recommended resource allocation among action categories for multiple ecosystems in each of four subregions, taking into account uncertainties about future resource availability, environmental drivers including frequency of near-term storm events and longer term sea level rise, and effectiveness of the allocations. Confirming and revising this decision frame entailed extensive stakeholder involvement (see section 7.2). The project design was structured such that CADS Phase 1 would be compatible with the Bayland Ecosystems and Habitat Goals Update (BEHGU), a technical update to the original Baylands Habitat Goals, which was being developed concurrently by a broad coalition of Bay Area scientists to develop management recommendations that account for projected climate change. This required much communication and coordination within the CADS leadership team itself along with communication and coordination between the leadership team and stakeholders, especially the BEHGU coordinators.

One stakeholder proposed that the decision frame should start by focusing on conserving tidal marsh alone, and that by including all estuarine ecosystems the problem became overly complex and some stakeholders viewed it to be intractable. Other stakeholders, however, were adamant that none of the estuarine ecosystems can be conserved in isolation and that the tradeoffs of biotic integrity between ecosystems must be considered. A compromise for future efforts would be to treat conservation objectives as constraints in all but one focal ecosystem. That way, the process could become more tractable by documenting effects on multiple ecosystems but focusing on maximizing conservation in just one focal ecosystem. Meeting the all the needs across such a diverse set of stakeholders presents an enormous challenge, and the leaders must make some tough choices when refining the decision frame that take all the opinions into account. However, such decisions are constantly being made by resource managers, as noted on multiple occasions by several participants.

Carrying out a project of this kind takes strong leadership involving a project coordinator with local knowledge, a lead expert in collaborative decision analysis and structured decision making, a workshop facilitator, and a core team of stakeholders. Although we did have each of these roles on this project, we believe that in future projects of this scope more resources should be devoted toward project coordination and management along with a broader commitment from a core team of stakeholders that can play a leadership role throughout the project. This would allow improved stakeholder engagement, improved documentation of the assumptions, synthesizing and distributing relevant information and preparatory materials, and more consistency in approaches used among subregional teams. It would also ensure clear timelines, tasks, and activities for generating and communicating products. For more detail on lessons learned from the decision-framing step of the project see Appendix H.

7.2 Engaging stakeholders and experts

In addition to having a deeply engaged core team of stakeholders (see section 2.2), engaging a broader suite of stakeholders is essential to ensure that the recommended allocations could be useful to inform actual on-ground decisions. Although there was broad representation of stakeholders during the orientation webinars and workshop, maintaining this engagement beyond the workshop required significant effort despite the original call for extended participation. Even though stakeholder groups recognized some early successes of the project and potential for improving conservation of estuarine ecosystems in SF Bay, they had not planned on committing time to the project beyond the workshop and were not able to elevate their commitment on short notice. There were at least 3 key questions raised by stakeholders that made them hesitant to commit additional time to CADS Phase 1: 1) added value of CADS over existing and ongoing conservation planning efforts; 2) feasibility of carrying out the project before the BEHGU process had been completed; and 3) carrying out the approach at a broad spatial extent before demonstrating at finer spatial scales within SF Bay.

The first two questions were addressed directly during the webinar series (see section 4.1), although they resurfaced during and after the workshop. It remains unclear how these concerns could have been better addressed. The third concern was only briefly addressed during the webinars and workshop, and this question about scaling of the decision question deserves greater attention. This question of scaling could be addressed as a decision on its own: should we invest resources in solving a decision question at a project scale before solving a decision question for each subregion? The main concern appeared to be that very few stakeholders were familiar with using the SDM process, and that addressing a decision question at a scale that goes beyond their traditional scale of decision-making leads to unusable products. The SF Bay does have a long history of conservation planning both at the project scale and through regional plans such as the 1999 Baylands Habitat Goals, Subtidal Goals, Tidal Marsh Recovery Plan and other agency plans, and the emerging BEHGU. The CADS leadership team in consultation with a core team that included BEHGU leaders came to a conclusion that the stakeholders of SF Bay were ready for a process to identify recommended allocations at the subregional scale. In response to ongoing stated needs to integrate management decisions from multiple projects on a subregional scale, the leaders believed it would be more efficient to start at this broader scale and then scale down rather than going in the reverse direction. Starting with project-level decisions would further the culture and paradigm of working at this scale rather than scaling up and coordinating across project borders at a subregional scale. Being vigilant and responsive to these concerns is essential to garner and maintain stakeholder engagement in a project of this scope.

By using a collaborative approach founded on structured decision making, we followed a framework that had been used successfully in past SF Bay conservation planning effort focused on tidal marsh and a smaller group of stakeholders and experts (Thorne et al. 2015). Although it was useful having a series of steps and toolbox to tackle such a complex problem, we found that much of the codified terminology was often confusing for this larger and more diverse group of stakeholders. We would recommend that future efforts use the principles of SDM while avoiding imposing the codified vernacular of SDM (e.g., fundamental objectives, means objectives, alternatives, consequences). Participants should be allowed to choose and define the terms they would like to use when referring to the steps and elements of SDM.

7.3 Identifying and defining conservation objectives

The leaders invested significant time extracting unique conservation objectives across a suite of existing conservation plans that span Bayland ecosystems, and this investment was valuable for ensuring that CADS Phase 1 began with a set of conservation objectives that represented many of the main concerns of stakeholders. Narrowing and refining the initial list to a tractable and conceivable set of conservation objectives then allowed the leaders to communicate with stakeholders to become more explicit about how these could become measurable attributes to be weighed against one another to represent their tradeoffs quantitatively. Having a draft set of conservation objectives and associated measurable attributes before the workshop was essential to ensure that draft decision tools could be completed during the workshop.

Although it would have been ideal to arrive at a final set of measurable attributes for biotic integrity during plenary at the workshop, the group was too large (ca. 30) to accomplish this with the time allowed. Instead, arriving at these attributes and defining them (along with assigning thresholds and binary categories) during breakouts of 3-7 stakeholders each was an effective approach. Some stakeholders wanted to choose attributes that were consistent across subregions, which in retrospect would have been a desirable outcome. With more time during the workshop, to alternate between breakouts and plenary, this would have been possible to achieve. As stated above, having an additional day for the workshop would lead to a better quality set of subregional products. The leaders proposed that common objectives emerging from the subregional groups (Table 6.1.3) could serve as a basis for addressing a decision question in the future that looks at how actions within subregions scale up to influence SF Bay-wide attributes of biotic integrity By having subregional scale objectives that were vetted by stakeholders, we were able to propose these regional-scale conservation objectives.

As we did for CADS Phase 1 at the subregional level, indicators could be rolled up into an index of biotic integrity for each ecosystem. The regional-level indicators would not replace those at the subregional-level, and they would instead provide a step towards developing recommendations that account for tradeoffs at the regional scale in addition to those at the subregional scale. These ecosystem-specific indices of biotic integrity could then be traded off against one another at the regional level in addition to the subregional level. There could also be tradeoffs between the regional-level and subregional-level conservation objectives. Not only could we then make a new set of subregional management recommendations that account for both subregional- and regional-scale indicators, but we could also make recommendations for monitoring and research on regional-scale indicators to improve expected conservation performance.

7.4 Identifying & refining action categories

From the start of the project, it was clear that the BEHGU recommendations as well as those from other regional plans (e.g., Subtidal Goals) would form a basis for the resource allocations to be recommended through CADS. The leaders spent much time reviewing draft BEHGU documents to identify action categories among which to allocate resources. This ensured that the recommendations from CADS would be compatible with those from BEHGU, supporting a collaborative atmosphere for broad-scale conservation in SF Bay.

Although there was broad agreement about action categories during plenary, some subregional groups altered the categorization as they were assigning resource allocations. Allowing for customized action categories makes the recommendations easier to interpret and be implemented within each subregion, but at the same time making it difficult to see how the recommendations compare among subregions. The approach (customized vs. common) to assigning action categories should be decided upon during plenary before developing the allocation options within subregions. Again, having more time for the workshop would allow for these discussions.

7.5 Developing resource allocation options

An agreed upon approach and draft template for developing resource allocation options helped ensure consistency among subregions in how they arrived at their recommendations. Having this a draft ready before the workshop allowed for more time to discuss other questions and issues during plenary and for the subregional groups to complete draft allocation options during breakouts. This template for resource allocations asked stakeholders to assign a percentage of resources to all possible combinations of action categories and Bayland ecosystems in which they would be applied. Having a draft final set of action categories and ecosystem classification before the workshop also helped ensure the subregional breakouts would have sufficient time to complete their draft decision tools. As there were only minor changes to the ecosystem classification and to action categories, it was quite easy adapting the allocation template accordingly.

Final ingredients for developing allocation options were future scenarios for resource availability and external environmental drivers (e.g. extreme storms). With deeper engagement of a core team of stakeholders, it would have been possible and very beneficial to have draft scenarios prepared before the workshop and justified based on existing models and projections. Instead significant time was spent in plenary developing these scenarios from scratch, taking away precious time from working through other portions of the decision tools.

Because the draft template and associated ingredients for developing allocation options were ready before the workshop or developed in plenary, breakout groups were able to focus on assigning percentages to the allocation-option tables. The leadership team had originally suggested that stakeholders work in pairs to assign percentages and then combine these afterword as a group, but it worked well for each subregional team to assign these percentages collectively. With a note-taker assigned to each breakout group, we would have better captured the reasoning for differences in percentages among action-category-ecosystem combinations for particular allocation options and differences in percentages between allocation options.

Although each subregional team revisited the allocation options following the workshop, there was only partial documentation for the reasoning behind the percentages. Particularly valuable would be translating each allocation option into a description of how this would be implemented under different scenarios for resource availability, by adapting draft recommendations from BEHGU.

Some stakeholders were surprised to see that the percentage allocations among ecosystems were quite similar between the two options in each of the four subregions (Figure 6.3.1). This raised a question of whether the stakeholders were really thinking about how investing in particular ecosystems might differ depending on their assumptions about external drivers for the future. For example, perhaps a significant greater percentage allocation toward migration space might be more warranted under a pessimistic future compared to an optimistic future for sea-level rise. Constructing additional allocation options for each combination of external driver scenarios (e.g., assume rosy resources but pessimistic sea-level rise) might generate more disparate allocation percentages among ecosystems when comparing the options.

When comparing allocation options among subregions, it was surprising for some to see the diverse ways in which subregions defined and allocated resources among ecosystems and among action categories (Figure 6.3.1 and Figure 6.3.2). For others, this made sense considering the differing acreages of ecosystems, differing threats to maintaining biotic integrity, and differing costs and constraints of taking actions among the subregions. By comparing resource allocations among subregions, stakeholders were able to evaluate whether their allocation options made sense within a broader regional context.

7.6 Making predictions about drivers and conservation outcomes

Having a diagram illustrating the decision frame (Figure 3.1.1) was a useful visual aid when communicating within the leadership team and with the broader suite of stakeholders. Although the decision frame was very broad in scope and depth, a simple flow chart was sufficient to capture the important pieces of the decision and laid the foundation for developing predictive models to inform the decision.

7.6.1 Developing influence diagrams

Of all the intermediate products generated through CADS Phase 1, the subregion- and ecosystem-specific influence diagrams were some of the most significant products. Not only did they integrate the elements of the decision with sufficient detail to be translated directly into decision tools, these had also never been done before in a particular subregion. In addition to providing a strong foundation for conducting a formal decision analysis, influence diagrams also provide the foundation for other values-focused conservation planning approaches such as Open Standards for Conservation (Conservation Measures Partnership 2013). The influence diagrams, then, can be used to inform conservation planning without requiring a formal decision analysis, albeit with less transparency in arriving at decisions.

7.6.2 Choosing measurable attributes and thresholds

Although subregional teams struggled initially to choose attributes to represent biotic integrity in each of their focal ecosystems, once chosen it was relatively straightforward for them to assign thresholds to create two levels of outcomes for each attribute. A commonly chosen threshold was stable/increasing vs. decreasing for the desirable attributes (e.g., Ridgway's Rail abundance) of biotic integrity during the near-term (2015-2029) and long-term (2030-2100) outcome horizons. Some stakeholders noted that this threshold might be insufficient when there is some acceptable level of decrease for a given attribute. For example, if Ridgway's Rails only decrease in numbers by 0.01%, then this could be considered acceptable. Stakeholders admitted, however, that identifying and agreeing on a non-zero threshold for change over time was next to impossible and very difficult to justify. Having clear instructions during breakout sessions was essential to ensure the subregional teams could complete at least a draft set of measurable attributes during the workshop.

7.6.3 Assigning probabilities to attributes

Although a probabilistic decision-analytic approach provided transparency in accounting for uncertainty when arriving at recommended allocations, populating the subregional decision tools with probabilities via independent elicitation was the most challenging and time-consuming step of the project. Although there was a concerted effort to keep the decision tools tractable, stakeholders were asked to fill in lengthy tables of probabilities (up to 64 per table) for attributes (up to 25) in the decision tools. Stakeholders were supportive of using such a probabilistic approach, and they invested much time, thought, and effort into filling out the probability tables to ensure they were of high quality and reflected their beliefs about estuarine ecosystems. They were aware that the recommended allocations depended largely on the probabilities they were providing. On the other hand, some found it difficult to find enough time to carefully complete all of the tables (especially the more lengthy ones) and to go back and revise following discussions with the decision analyst and the other stakeholders on their subregional team. Finding the right balance between representing all the potentially important uncertainties (and therefore making the decision tool more complex) and keeping the decision tool tractable is a great challenge within a complex conservation context. The probabilities provided by stakeholders reflected their own knowledge, which in some cases did not take into account all the available and relevant literature and knowledge about the drivers and indicators of biotic integrity. The subregional decision tools were designed to accommodate new information through adjusting the input probabilities and therefore updating the management recommendations in an iterative fashion.

There are four key steps that help facilitate an elicitation process in this kind of decision context. First, only include in the decision tool only those factors that have uncertain and potentially large effects on the conservation objectives. Second, discuss the approach to eliciting probabilities in plenary during the stakeholder workshop, using a hypothetical example from a non-focal ecosystem (see Appendix D-4). Third, write out a clear question for each attribute in the decision tools, so that stakeholders can understand what was being asked when filling in their probabilities. Fourth, during workshop breakouts, the stakeholders independently fill out probabilities for 2-3 attributes and then discuss summary statistics as a group with a decision analyst to catch any widespread misunderstandings. Fifth, allow for multiple rounds of independent elicitation that include discussions with the subregional group members to rectify any logical inconsistencies and outliers. This is a time-consuming process, but this kind of time investment is needed to ensure reliable recommendations in absence of existing numerical models that can be used to provide the probabilities.

Some of the subregional teams expressed concerns about consistency in the interpretation of what was being asked when assigning each probability. During a series of webinars they discussed the variation among team members' probabilities (presented anonymously). After resolving outliers and noting that trends in the probabilities across combinations of driver categories, these teams became more confident about using the averages of probabilities as inputs to the decision tool (see section 3.5.3). Another concern was about the cognitive challenge of filling out lengthy tables of probabilities and keeping track of many combinations of levels for drivers (the longest was $64 = 2^6$, for attributes linked to 6 drivers). Team members were committed to providing high quality probabilities, however. They were willing to have additional conference calls and individual calls to discuss the elicitation process and input values. It is valuable having a coach or team leader available to assist participants and answer questions.

Two types of attributes presented particular challenges for assigning probabilities. First, when the resource allocation and resource availability were drivers of an attribute this required an extra step of checking the influence diagram and allocation percentages and then applying the resource-availability to the percentages for the relevant action categories. The reliability of the recommendations would be greatly improved if there were predictive models that could provide the needed probabilities in place of relying on expert elicitation to predict effectiveness of allocation options under contrasting scenarios for external environmental drivers and resource availability. The multiple dimensions of such an elicitation can exceed cognitive capacities. Second, change in biotic integrity was a conservation objective for each ecosystem and outcome horizon. Stakeholders had to consider the representativeness of multiple attributes of biotic integrity (e.g. Ridgway's Rail population trend) when assigning probabilities to change in biotic integrity. A venn diagram (Figure 4.5.2) was useful to illustrate how the representativeness of each attribute, some of which might represent the same ecosystem attributes, reflects biotic integrity as a whole.

Some stakeholders suggested that the elicitation should ask for notes and justification for the reasoning behind the probabilities being provided by each stakeholder. These justifications are helpful for the decision analyst to check for logical inconsistencies in the probabilities, and to catch any misunderstandings about what was being asked for each attribute. Most stakeholders did provide some justifications either voluntarily or upon request from the decision analyst. Having justifications for all probabilities, although requiring additional time on the part of the stakeholders, would help ensure more reliable recommendations.

One stakeholder proposed that future elicitation processes should assume a constant value for resource availability (rather than addressing the uncertainty via the rosy and not-so-great scenarios). By including this additional dimension to the uncertainty, it slowed them down and compromised the quality of their probabilities and they questioned the quality of other stakeholders' probabilities as a result. Other stakeholders were glad that uncertainty about resource availability was included, because it could have such a large effect on the trajectory of biotic integrity of estuarine ecosystems even above and beyond the effects of environmental drivers and the allocation alone. Nonetheless, we found that the recommendation remained the assume-rosy-future allocation regardless of the projected resource availability scenario (see section 6.6). Although we found that the uncertainty about resource availability did not influence the recommendations, by ignoring it we would be left with some doubt about the robustness of the recommendations.

7.7 Identifying & quantifying trade-offs

We focused on two types of tradeoffs: 1) changes in biotic integrity among each of the four estuarine ecosystems for a given outcome horizon; and 2) changes in biotic integrity between outcome horizons for a given estuarine ecosystem. An alternative approach would be eliciting tradeoffs among ecosystem-specific attributes of biotic integrity, between outcome horizons, and among ecosystems. This alternative approach would have generated an extremely large number of outcome scenarios, to which stakeholders would then need to assign utility values. The leaders chose a simpler set of tradeoffs that were not only feasible to quantify but also better represented the ways stakeholders think about the tradeoffs: between ecosystems and between outcome horizons. The biotic integrity attribute did capture the representativeness of each ecosystem attribute, and stakeholders agreed this was a reasonable way to account for the many dimensions of tradeoffs in this decision context. Almost all the lessons learned about assigning probabilities to attributes (see section 0 above) can be applied to quantifying trade-offs.

7.8 Identifying recommended allocations and main findings

We found it to be very useful being able to provide explicit resource allocation options for each subregion that account for future uncertainties about external drivers (i.e., those beyond the control of the stakeholders) including climate change and availability of sediment and resources (funding, staff, equipment). This way, stakeholders have actual percentage-based recommendations for guiding how to allocate resources among action categories within each of six Bayland ecosystems in four subregions of the SF Bay. The recommended allocations emerged from decision tools that allow stakeholders to make quantitative predictions about changes in indicators of biotic integrity and biotic integrity as a whole in each of four estuarine ecosystems in each subregion. By seeing these probabilistic predictions, stakeholders have a specific and common perspective on the degree of uncertainty surrounding their desired conservation outcomes under each resource allocation option.

Furthermore, the decision tools are amenable to sensitivity analyses that easily allow stakeholders to ask "what if" questions. For example, what if we do end up having more than double the resources as we do currently? Does that change the recommendation? How does uncertainty about the desired conservation outcomes differ between the resource availability scenarios? The decision tools also allow stakeholders to quantify the expected increase in conservation performance if particular what-if questions are resolved through further research and analysis. We conducted sensitivity analyses that revealed recommendations for further research on resolving uncertainties about responses of particular indicators of biotic integrity to the resource allocation options (Table 6.6.1). This provides important guidance for biologists and analysts to collect information that will be most helpful for informing management decisions.

Through the CADS project we have also identified specific challenges and opportunities for conservation at a subregional level. For example, stakeholders realized there is a lack of available migration space for the estuary to move into within South Bay but there are such opportunities in North Bay.

7.9 Next steps and suggestions for adapting subregional CADS tools

The North Bay and South Bay teams incorporated both near-term and long-term factors into their decision tools, and so they arrived at recommendations for both management time periods (2015-2029 and 2030-2050). The Suisun and Central Bay teams created allocation options for both management time periods, and the next step is to finish the respective long-term influence diagrams and elicitation process to assign predictions and utility values within their subregional decision tools. Once completed, we would have completed decision tools and recommended resource allocations within two management time horizons for all four subregions. With the completed decision tools for Suisun and Central Bay, we could conduct additional sensitivity analyses to see if expected performance in the long-term could be enhanced by conducting additional research and analysis in the near-term. If near-term changes in ecosystem acreages (e.g., upland transition zone) are included as drivers of long-term changes in another ecosystem (e.g., tidal marsh), then we could evaluate whether changes in these near-term factors would affect the longer-term recommendation for resource allocation. If that is the case, then we can quantify the value of monitoring changes in acreages of these ecosystems in the near-term. This would be an example of state-dependent decision making and adaptive management that has been implemented by natural resource management efforts in other parts of the U.S. (Gannon et al. 2013, Smith et al. 2013).

The management recommendations and associated subregional decision tools were the product of many discussions and input from targeted stakeholder groups. Although great effort was taken to ensure that the tools would best represent the management questions faced by stakeholders and accurately accounted for crucial sources of uncertainty (regarding management effectiveness and external drivers like extreme storms), we realize that the decision tools can be improved. First, the current influence diagrams and predictions could be evaluated by experts that were not involved in developing the subregional decision tools to ensure that they are taking into account the relevant scientific information. Second, we identified some key sources of uncertainty about effects of resource allocations on indicators of biotic integrity. We found that if these focal uncertainties are resolved, then the recommended allocations could change and therefore improve expected conservation performance. For example if a new study revealed that the allocation assuming a pessimistic future was more likely to result in stable or increasing populations of focal bird guilds in managed ponds of South Bay compared to the allocation assuming a rosy future, then this would lead to a recommendation to implement the assume-pessimistic allocation instead of the assume-rosy allocation and would lead to greater expected conservation performance in South Bay.

7.10 Revisiting challenges and goals

Here we revisit the motivating challenges and goals for CADS Phase 1, which were presented in 0. The first goal was addressing challenges that emerged from previous and ongoing conservation planning efforts, and then there were three additional goals identified.

7.10.1 Challenges addressed

1) *Engage a broader suite of stakeholders and experts to develop a platform for coordination among conservation partners working within and/or across subregions of SF Bay, including natural resource managers, conservation coordinators and planners, and scientists*

The orientation webinars and stakeholder workshop brought together 27 stakeholder groups and experts (Table 2.2.2). Following the workshop, subregional working groups became more familiar with one another’s perspectives, how their management decisions impacted surrounding habitats beyond the footprint of their project areas, and how they could work together to conserve estuarine ecosystems. The products of this project will be available online through the San Francisco Bay Joint Venture and California Climate Commons websites, where any stakeholder can download them and use them for informing their conservation planning in SF Bay. This challenge (#1) was therefore addressed, but it will take continuous effort from stakeholders to continue the collaborations and to pursue opportunities to coordinate on conservation efforts at the subregional level. SF Bay Joint Venture provides a platform and encourages such long-term collaborations and coordination.

2) Account for subregional differences with regard to the costs and constraints of taking climate-adaptation actions, suites of conservation objectives, and uncertainties regarding management effectiveness, sediment dynamics, and climate-change impacts.

Each subregional team composed of 3-7 stakeholders and a decision analyst completed a decision tool to identify recommended resource allocations over a near-term (2015-2029), and two of the subregional teams arrived at recommendations for a longer-term (2030-2100) management horizon. Each decision tool took into account tradeoffs among biotic integrity in four estuarine ecosystems, while accounting for several sources of uncertainty about the future including climatic conditions and impacts, available resources, and effectiveness of allocation options, and sediment dynamics. Uncertainty about sediment dynamics was incorporated as an explicit driver within a subset of ecosystems for some of the subregions, but it was considered implicitly as an intermediate driver throughout the ecosystems and subregions. The challenge was largely addressed, but further work is needed to complete the long-term (2030-2100) portion of the decision tools for Central Bay and Suisun.

3) Address the linked nature of decisions, objectives and outcomes across time and space. Decisions about project-level actions taken in the near future should account for the consequences of actions taken in the more distant future. Likewise, decisions should account for project-level actions scaling up to influence the subregional and regional-level objectives.

These linkages were discussed at length in the South Bay team following the workshop, with particular emphasis on allowing for estuarine ecosystems to migrate upward with sea-level rise in the long-term. Although this ecosystem migration was included as a driver in the influence diagram for the long-term portion of the decision tool, one of the two linkages (near-term allocation effect on total upland transition zone acreage in the near-term, which was linked to long-term tidal marsh acreage) was mistakenly dropped from the elicitation. By the time the team realized this, there was no time left to redo the elicitation for those linked elements. The one linkage that was included was the effect of change in tidal marsh acreage in the near-term (2030-2100) on the acreage of subtidal and intertidal mudflats in the long-term (2030-2100). Based on the sensitivity analysis, the recommended allocation in the near-term was insensitive to uncertainty about the strength of this linkage. The South Bay team also discussed linking the near-term outcomes to the baseline starting values for changes in attributes of biotic integrity during the long-term horizon. It became evident, however, that by adding these temporal linkages on top of the other linkages (e.g., effects of longer-term allocation and resource availability) would make the elicitation process intractable.

The North Bay team also discussed these linkages, but the stakeholders believed the linkages were too weak to warrant their explicit inclusion and added complexity in the decision tool. Instead of being included as explicit drivers of the long-term elements in the decision tool, the linkages were included as implicit drivers to avoid overcomplicating the decision tool and elicitation process.

Incorporating these temporal linkages in a more thorough and careful fashion remains an open challenge for conservation planning in SF Bay. Doing so would require continuing the work started in this project and having the subregional teams complete the long-term portions of their decision tools, while carefully incorporating and considering these temporal linkages.

4) Incorporate additional system components, including habitat types (e.g. tidal flats, low marsh, mid-marsh, high-marsh, upland transition, managed ponds) and species of conservation concern with contrasting requirements compared to Ridgway's Rail (e.g., salt marsh harvest mouse, shorebirds). Consider especially tradeoffs with respect to contrasting responses of multiple species/communities and associated transitions of spatial elements from one estuarine environment type to another.

Each subregional decision tool considered tradeoffs of changes in biotic integrity among 3-4 focal estuarine ecosystem types that were represented by a diverse set of indicators (Table 6.1.2). Within each ecosystem for each subregion, change in biotic integrity was modeled as a function of 1-6 attributes of that ecosystem. This challenge was fully met for the near-term (2015-2029), and met for two of the four subregions (North Bay and South Bay) in the long-term (2030-2100) horizon.

5) Consider a broader response horizon going out to 2100 to bring in the full range of uncertainty about future sea-level rise.

Two of the four subregions completed the long-term (2030-2100) portions of their decision tools, and for these subregions this challenge was addressed (but see challenge 2, above). In the remaining subregions, allocation options were developed with the mindset that these actions would prepare ecosystems for sea-level rise over the long-term. Completing these long-term elements remains a challenge for two of the subregions (Central Bay and Suisun), however.

6) Inform design of an adaptive management and monitoring program that guides and evaluates the climate adaptation strategy by addressing key sources of uncertainty with high value of information.

In each of the four subregions, we identified sources of uncertainty that if resolved would be expected to improve conservation outcomes by 4-8% (see section 6.6).

7.10.2 Goals achieved

1) *Arrive at recommended resource allocations that cut across jurisdictional boundaries to conserve estuarine ecosystems within each subregion of SF Bay*

Each subregional team identified recommendations for allocating resources (near- and long-term) among action categories within focal estuarine ecosystems throughout their subregion. This meant that stakeholders had to think beyond their jurisdictional boundaries when developing allocation options and then linking these to subregional-scale outcomes for biotic integrity in each of their focal estuarine ecosystems. This goal was achieved for the near-term (2015-2029) management horizon in all subregions, but arriving at cross-jurisdictional allocations in the longer-term (2030-2050) remains a challenge.

2) *Provide basis for discussion when consulting with partners on their individual projects as part of the San Francisco Bay Joint Venture (SFBJV) Design Review Program*

While funding for the SF Bay Joint Venture Design Review Program will expire in Spring 2015, this recommendation may help provide an argument to seek funding to continue the program. The SFBJV does informally discuss project design with members of the Conservation Delivery Committee who provide input to project proponents/managers. The CADS tools will further inform such discussions.

3) *Identify suite of measurable conservation objectives from regional to subregional scales that can be communicated in the upcoming revision to the SFBJV Implementation Strategy*

Each subregional team identified indicators of biotic integrity for 3-4 focal estuarine ecosystems within their subregion (Table 6.1.2). Two of the subregions also included measurable attributes representing concerns about flood protection for human infrastructure along SF Bay. Other human dimensions (e.g., recreation opportunities, vector-borne disease) were considered as implicit rather than being incorporated explicitly in the decision tools. This goal was one of the most significant achievements of CADS Phase 1, and these measurable attributes will be incorporated within the upcoming revision to the SFBJV Implementation Strategy . This is the real basis for learning and adapting to ultimately achieve desired conservation outcomes.

7.10.3 Decision-analytic tool

Some stakeholders were uncomfortable with using a relatively advanced decision-analytic tool (Bayesian decision network; BDN) that requires specifying probabilities of drivers and outcomes for attributes of biotic integrity. A consequence table and simple multi-attribute rating technique (SMART) comprise a simpler decision-analytic tool (Hammond et al. 1999) that can be applied to identify a recommended allocation that considers tradeoffs among competing objectives under uncertainties such as future resource availability. Instead of requiring probabilities as inputs, SMART requires deterministic predictions for magnitudes of outcomes (e.g., 10% change in Ridgway's Rail abundance). These magnitudes are then converted to a common 0-1 scale for each indicator based on the range of possible outcomes for each, and these scores are then used to generate an expected performance score for each management option based on elicited utilities for outcome scenarios – all of which can be done easily in a single spreadsheet.

Although SMART does not require probabilities nor specialized software, there are three advantages of using a Bayesian decision network. First, a BDN is structured as an influence diagram, and so it is straightforward to see how external drivers and allocation options are linked to the indicators via intermediate drivers within the decision tool itself. Second, addressing many sources of uncertainty simultaneously using SMART is quite cumbersome compared with using a graphical interface of a BDN. Third, a BDN accepts attributes with two levels (e.g., stable/increasing vs. decreasing

Ridgway's Rail population), whereas SMART requires having at least three levels or ideally a continuous distribution for each indicator. SMART, however, could be used to identify irrelevant attributes representing the conservation objectives and therefore reduce the complexity of the decision tool to be developed as a BDN. The decision analytic tool must be chosen based on the dimensions of the decision question and number of uncertainties to be addressed, along with the available expertise to build and use it.

7.10.4 Sensitivity analysis

In addition to providing management recommendations, we were also able to provide recommendations for conducting further research and analysis to resolve uncertainties about management effectiveness for indicators of tidal marsh in each of the subregions. We found that this additional research could improve the expected performance of the chosen resource allocations[19]. This information is useful to guide researchers in targeting particular questions to address that can help improve conservation decisions in the Baylands.

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Glossary of terms and abbreviations

Actions – specific steps to be implemented on the ground for achieving stated conservation objectives, specified for individual projects or segments. For the purpose of identifying recommended courses of action, multiple discrete actions can be combined into categories of actions.

Action category-- a set of conservation actions that are related in some way, e.g. a manage-water category could include management actions that affect water levels and water quality. An action category allows for reduced complexity when developing alternative management options.

Allocation options/Allocate – proportional expenditures among alternative conservation actions or action categories. An allocation may be specified for implementation at a single point in time or space, or for a series of implementations over time and across space.

Bayesian decision network (BDN) – a decision analytic tool that provides a recommended allocation by explicitly accounting for uncertainty about the effects of allocation options and external drivers on conservation objectives, along with how stakeholders tradeoff potential outcomes for the objectives.

BCDC – San Francisco Bay Conservation and Development Commission

BEHGU -- Baylands Ecosystems Habitat Goals Update, which will provide recommendations for conservation actions across the Baylands surrounding SF Bay, subregions within the Baylands, and segments within subregions. The recommendations will account for future climate change.

Biophysical attributes -- attributes of an ecosystem including all the abiotic (e.g., sediment) and biotic (i.e., living organisms) components.

Biotic attributes -- attributes of an ecosystem including all the biological (i.e., living organisms) components.

CADS Phase 1 – Climate Adaptation Decision Support, focusing on developing recommended resource allocations for conserving the SF Bay Estuary.

CADS Phase 2 -- Climate Adaptation Decision Support, focusing on developing recommendations for adapting to climate change in a focal conservation area, San Pablo Bay National Wildlife Refuge.

CALCC – California Landscape Conservation Cooperative

CDFW – California Department of Fish and Wildlife

Climate-smart restoration actions — changes to current or planned projects in tidal marshes to increase resiliency of the areas to sea-level rise effects.

Conceptual model – a diagram showing how resource allocations and external drivers are linked with conservation objectives, taking into account time scales, constraints, and uncertainties. This conceptual model forms the basic structure of a quantitative decision tool.

Consequences –predicted outcomes produced by actions. These can be represented by models that link actions to outcomes reflecting the fundamental objectives. Models can provide guidance for selecting a management alternative through optimization. Tools for optimization include, but are not limited to, consequence tables, decision trees, and search algorithms.

Conserve/Conservation -- either maintain or improve the biophysical properties and dynamics of an ecosystem or set of ecosystems over multiple decades, often with explicit consideration of human dimensions. Desired properties and dynamics are specified by stakeholders and decision-makers.

Conservation objective – ultimate desired outcome (aka: fundamental objective) to be achieved by decision makers and other stakeholders through conservation actions that could be taken. Can be an overarching phenomenon that cannot be directly measured (e.g., biotic integrity) but must be associated with one or more indicators.

Constraint -- in the context of a conservation objective, a threshold level for a particular conservation objective beyond which would be unacceptable to the decision makers. In the context of an action, a limit on the range or types of actions that can be taken based on laws, regulations, or public acceptance.

Decision analysis/analytic -- a quantitative approach to identifying recommended course of action that maximizes the expected performance of one or more fundamental objectives. Decision analysis is founded in decision theory, with roots in mathematics, computer science, and economics.

Decision (analytic) tool or model-- a model providing the structure for a decision analysis (see above), which is often based on the structure of an influence diagram (see below).

Decision frame / framing – description of decision to be made, including the type of decision to be made (e.g. resource allocation or discrete choices), regulatory context, relevant decision-makers and stakeholders, and spatial and temporal scales.

Decision question -- concise, one-sentence question highlighting the important issues needed to be addressed as part of the decision(s), including generalized objectives, management options, constraints, and uncertainties.

Decision maker – person or group that is responsible for policy and practices to be implemented. The decision maker may consider input from multiple stakeholders, such as state, county, city, and federal agencies.

Elicit/Elicitation -- process of acquiring quantitative predictions from technical experts or utility values from stakeholders. This information is then used in a decision analysis. Elicitation is often conducted independently and anonymously.

Enhancement - process of improving the function of an existing, but degraded ecosystem so it can better support the various animal and plant communities of interest (e.g. planting trees along creeks to provide more shade and improve the function of a riparian corridor for fish species).

Estuarine ecosystems-- for this project we define these to include environments from the subtidal zone, tidal flats through the upland transition zone.

Expected conservation performance (expected utility)—quantified prognosis for conservation outcomes, taking into account tradeoffs among ecosystems and/or time horizons from the perspective of one or more stakeholders, that would be achieved through a particular resource allocation option.

External driver -- factor that affects conservation objectives but is beyond the control or influence of the relevant decision makers and stakeholders. Examples include climatic conditions, resource availability, and decisions or policies enacted by upper government levels.

Extreme events –significant deviations from normal weather patterns, usually described as heat waves, storms, floods, and droughts.

Factor – refers to any element within an influence diagram or decision tool, including conservation objectives, intermediate drivers, external drivers, and actions or action categories.

Framing a decision – see **Decision framing**.

Fundamental (conservation) objective – an ultimate desire or endpoint to be achieved by the decision makers and other stakeholders through conservation actions that could be taken. Can be an overarching phenomenon that cannot be directly measured (e.g., biotic integrity) but must be associated with one or more indicators.

Human dimensions -- issues and concerns regarding the well-being, health, and safety of humans in relation to biophysical conditions of an ecosystem or set of ecosystems.

Indicators – attributes of a conservation objective (e.g., stable/increasing biotic integrity) that can be measured or predicted (e.g., stable/increasing abundance of Ridgway's Rail and salt marsh harvest mouse).

Influence diagram -- diagram linking actions or action categories and external drivers to fundamental objectives, often via intermediate outcomes. This diagram can form the structure of a quantitative, decision tool.

Intermediate drivers/outcomes -- within a decision tool, these are effects of an external driver or an action (or set of actions) that in turn affect at least indirectly the conservation objectives. Referred to in structured decision making literature as 'means objectives'.

Manage(ment) - land management practice that seeks to conserve, protect, restore and enhance habitat areas for wild plants and animals, especially conservation reliant species, and prevent their extinction, fragmentation or reduction in range.

Management horizon (time period) – period of time over which management actions are implemented on the ground.

Marsh-migration actions -- protection of adjoining terrestrial environments to allow for upslope migration of tidal marsh with sea-level rise.

Means objectives – see **Intermediate drivers.**

Measurable attribute / metric - quantitative units (e.g., population size) for an indicator or driver in an influence diagram, which enables quantitative predictions to be assigned.

Models –ways to represent logic for making predictions of outcomes and consequences of actions and external drivers.

Netica –a freely available computer program for developing and analyzing Bayesian networks.

NPS – National Park Service

Objectives – what stakeholders strive to achieve through management actions.

Objectives hierarchy – a diagram used in structured decision making that represents the nested nature of conservation objectives. This tool is helpful in identifying ultimate desired outcomes to include in a decision tool.

Optimization – identifying a resource allocation providing the most desired outcome (i.e., maximum expected performance/utility) among a set of allocation options, which usually involves quantitative decision analysis.

Outcome -- refers to a predicted future condition of an intermediate driver or conservation objective.

Outcome horizon -- a particular year or range of years over which the results of conservation actions would be intended or evaluated.

Prediction – statement, often quantitative, about what will happen in the future regarding a physical (e.g., extreme storms) or biological (e.g., shorebirds) phenomenon.

Project - an individual or collaborative enterprise that is carefully planned and designed to achieve a particular aim in the context of natural resources management and conservation.

Protection -- habitat protection in fee title, easement, or management actions that achieve the intended land protection goal.

Recommended allocation-- a conservation or management allocation that is most likely to provide a desired outcome (i.e., maximum expected performance or expected utility) among a set of allocation options. The recommended allocation can be identified using decision analysis and optimization. See also **Allocation.**

Resources / resource availability-- time, money, and staff available to implement conservation actions

Restoration – the action of turning converted landscapes into functional ecosystems to provide habitat for wildlife and plants

Robust allocation-- an allocation option that is recommended regardless of uncertainty about the outcomes in terms of the conservation objectives and their drivers.

Scenario -- a possible future set of conditions regarding resource allocations, external drivers, intermediate drivers, and/or indicators.

Segment -- geographic portions within subregions of SF Bay, each usually encompassing multiple conservation projects; the 20 segments are mapped in the 1999 Bayland Goals

Sensitivity analysis – examine how the optimal decision and the expected outcome is affected by uncertainty about system dynamics and management effectiveness.

SF Bay – San Francisco Bay

SFBJV – San Francisco Bay Joint Venture

Stakeholder -- an individual or entity who has direct influence or is influenced by a particular decision or set of decisions.

Structured decision making (SDM) – a process and organized analysis of a problem in order to reach decisions that are focused clearly toward fundamental objectives. It is based in decision theory and risk analysis.

Subregion -- geographic divisions within SF Bay; the four subregions are mapped in the 1999 Bayland Goals (Goals Project 1999).

Tradeoffs – quantified levels of satisfaction or happiness that one or more stakeholders assign to scenarios or possible outcomes for multiple conservation objectives. See also **Utility.**

Upland transition zone – open space where marsh transgression is possible upslope

USACE – U.S. Army Core of Engineers

USFWS – U.S. Fish and Wildlife Service

Utility (value) –quantified value a manager places on a possible outcome in terms of a conservation objective or set of conservation objectives, which may be maximized in a quantitative decision analysis. See also **tradeoffs.**

Value of information -- the value of collecting new information in terms of how much the fundamental objectives would improve, accounting for uncertainty, after collecting that information and incorporating that into decision making.

Appendix A **Upland transition zone projections**

This appendix was developed by Brian Fulfrost and David Thomson.

Background

Estuarine-Terrestrial Transitional Habitats (hereafter "transitions") are defined by Thomson et al (2013) as:

Estuarine-terrestrial transitional habitats occupy the boundary between land and sea,

from the zone of regular flooding to the effective limit of tidal influence.

They harbor a unique plant community, provide critical wildlife support to adjacent ecosystems,

and play an important role in linking marine and terrestrial processes.

Their character, distribution and extent vary substantially throughout the estuary, controlled primarily by the interaction of topography and the tides. Humans have severely impacted transitions, particularly over the last few centuries, with loss estimates exceeding 90%. A primary driver of this was land "reclamation", which disconnected large tracts of habitats from both estuarine and riverine influences. In most cases the transitional topography still exists, but does not provide the needed ecosystem functions. However they could if reconnected to the estuary and managed for the needed habitats.

As a result, SFBBO in conjunction with Brian Fulfrost & Associates (BFA), developed a GIS based decision support system (DSS) to identify and prioritize tidal marsh-upland ecotonal habitats (transitions) to assist land managers in restoring and protecting San Francisco Bay's (estuary) tidal marsh ecosystem (Fulfrost and Thomson 2015).

The DSS takes a strategic approach towards decision support, by accounting for the landward migration of high marsh and other transitional habitats in response to predicted sea level rise (SLR). Current documents do not adequately describe ecotonal habitats, quantify the amount needed to aid listed species recovery while allowing for SLR, nor prioritize specific sites for protection and restoration. The DSS was developed with regional specialists to describe transitional habitat characters that are important to the tidal marsh ecosystem.

Methods

The transitional zone is largely determined by the extent of the tidal zone, the salinity of the soil, and the consequent distribution of flora. The first component of the transitional zone decision support was to map the potential transitional zone based on tidal and elevation constraints. The resulting landscape-scale transitional topography maps show their current distribution and extent. The few still connected to the estuary are termed "existing transitions"; those disconnected by water control structures (such as levees) are termed "potential transitions". These transitions, when viewed with the distribution and extent of tidal marshes can help managers visualize where they are lacking (i.e. requiring creation) and where they are plentiful (i.e. requiring protection). Transition zones were also mapped according to two Seas Level Rise time horizons (“high” 2050 = 61cm; “high 2100 = 167cm) identified by the National Research Council (NRC 2013), in order to predict likely changes in distribution and extent through time.

Results and Discussion

Although the movement of transitions away from the estuary was predicted, Fulfrost and Thomson's research found that the extent (i.e. acreage) of transitions will diminish over time because the tidal elevation required for transitions zone decrease as slopes generally increase with distance from the estuary (see table and graphs below). Simply put there will be less acreage of upland transitional habitat in the future surrounding the estuary.

Existing transitions (i.e. connected to the estuary) are projected to be eliminated by SLR around 2100, so they must either be created through filling the estuary or levees moved to reconnect potential transitions to the estuary. Creating transitions requires filling the estuary, converting lower elevation habitats into higher ones in preparation for future sea levels. Identifying which is more feasible, massive earthwork projects or moving levees and purchasing large tracts of land, will require landscape scale planning projects. Our DSS would provide useful information to such a project, but is primarily designed to help managers identify where their resources will provide the greatest impact.

Fulfrost and Thomson have begun enhancing their DSS by creating an indexed set of metrics that utilize commonly available regional datasets to characterize the transitions, already identified by tidal elevations, by their quality for tidal marsh ecosystem management. These data allow the DSS to improve the identification of sites by management where restoration or enhancement actions are of greatest value. The final output of the DSS is a GIS that identifies transitional topography and ranks them according to their value to tidal marsh ecosystem management.

Although beyond the scope of Fulfrost and Thomson's project, it is likely the most usable topography for estuarine-terrestrial transitions will be up the river valleys. Currently these areas are wetlands of varying salinities or riverine-upland transitions (aka riparian habitat), but SLR will cause the estuary to colonize them, raising salinities and changing habitat types. If the future extent of salinity zones could be modeled then a project such as ours could be utilized to predict the future distribution and extent of tidal salt and brackish marsh-terrestrial transitional habitats up these valleys, which could be prioritized for conservation of the future tidal marsh ecosystem.

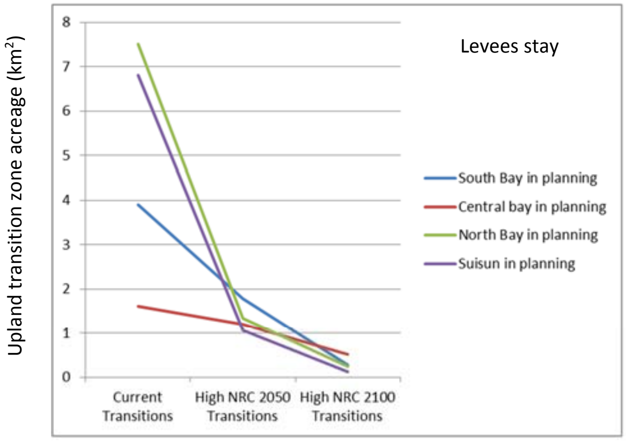
References

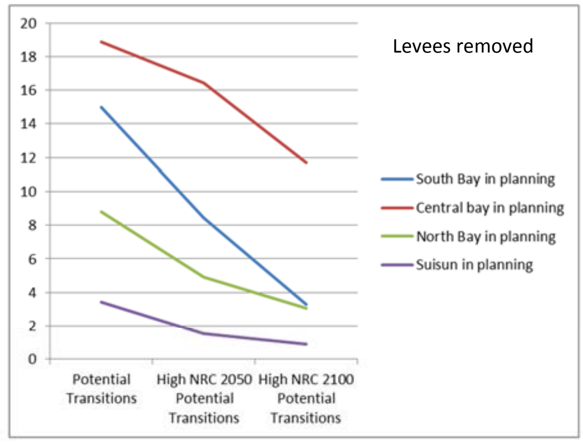
Thomson, D., et al. Critical Tidal Marsh Ecosystem Habitats at the Bay's Margin : A description. December 2013. Report of pilot project produced for USFWS Coastal Program.

Fulfrost, B., and Thomson, D. San Francisco Bay Margin Conservation and Management Decision Support System (DSS). April 2015. Report of pilot project produced for USFWS Coastal Program.

		Current and Projected Upland Transition Zone Habitat (km^2)					
Subregion		**Current**		**High NRC SLR 2050 (61 cm)**		**High NRC SLR 2100 (167 cm)**	
		tidal	non-tidal	tidal	non-tidal	tidal	non-tidal
North Bay	inside	7.50	8.79	1.33	4.90	0.25	3.06
	outside	-	2.86	0.00	2.21	0.00	4.32
Suisun	inside	6.80	3.42	1.07	1.53	0.12	0.88
	outside	-	0.69	0.00	0.57	0.00	1.01
Central Bay	inside	1.61	18.86	1.20	16.42	0.52	11.68
	outside	-	1.03	0.00	2.16	0.00	4.34
South Bay	inside	3.90	14.97	1.78	8.45	0.28	3.27
	outside	-	20.75	0.00	17.37	0.00	19.06

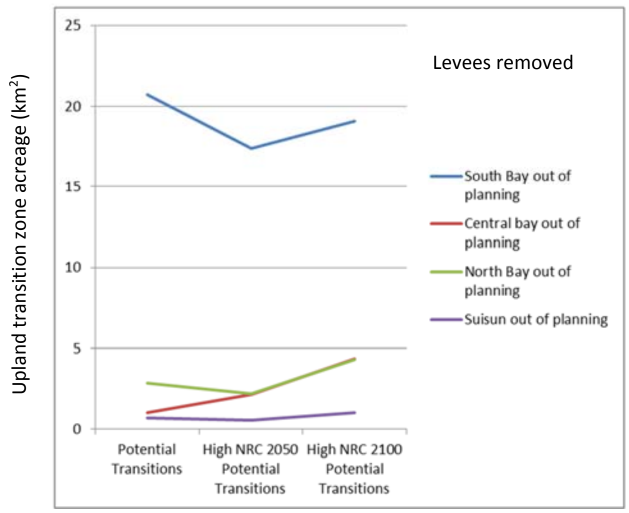
NRC = National Regulatory Commission; SLR = sea-level rise; inside = within planning area of SF Bay Estuary; outside = beyond planning area of the Estuary.





No upland transition zone beyond planning boundary of Estuary if levees stay

Note that vertical axes differ among graphs.



Appendix B **Timeline for CADS Phase 1.**

Timeline for stakeholder engagement and developing Bayland wide products and subregional decision tools to inform conservation of estuarine ecosystems of SF Bay.

Months	Stakeholder activities	Leadership team activities	Products on CADS website[a]
2013			
August-December		Initial decision framing; Coordinating with leaders of BEHGU on project design	
2014			
January		Scheduling orientation webinars and workshop with core team and all stakeholders; Launching CADS website; Preparing for core team webinar; Drafting invitation for workshop	Save-the-date message for workshop
February	Webinar with core team (Feb. 3rd)	Addressing core-team suggestions for decision framing and stakeholder participation; Preparing for workshop and engaging stakeholders	Powerpoint presentation from core-team webinar; Compilation of core-team suggestions
March-April	Orientation webinars with stakeholders (April 2nd, 16th, 23rd, 30th)	Preparing for workshop and orientation webinars; Refining decision frame; Engaging stakeholders; Reviewing objectives in existing conservation plans; Identifying draft action categories from BEHGU; Responding to questions and comments between webinars; Recruiting second decision analyst	Powerpoint presentations from webinars
May	Workshop with stakeholders (May 20-22nd)	Preparing for workshop; Engaging stakeholders; Refining proposed decision frame	Decision frame; Conservation objectives; Classification of Bayland ecosystems; Action categories; Approach to develop allocation options; Approach to recommend an allocation

a https://sites.google.com/site/sfbaystructureddecisionmaking/

Timeline for stakeholder engagement and developing Bayland wide products and subregional decision tools to inform conservation of estuarine ecosystems of SF Bay, continued.

Months	Stakeholder activities	Leadership team activities	Products on CADS website[a]
2014			
June-December	Completing elicitation process; participating in webinars	Completing elicitation process; conducting decision analysis; organizing webinars; and discussing results	
2015			
January-February	Completing elicitation process; participating in webinars	Completing elicitation process; conducting decision analysis; organizing webinars; drafting report; and discussing results	

Appendix C **Information packet outline for stakeholder workshop**

1) Opening letter and orientation -- how to use this info packet
2) Workshop agenda and expected outcomes
3) CADS Fact Sheet
4) Team composition
    a) Leadership Team
    b) Core Team
    c) Webinar participants
5) Short history of CADS prototype development: 2011 SF Bay SDM workshop until present
6) Current prototype decision structure (still in draft)
    a) Decision question and framing
    b) Objectives and drivers
        i) Hierarchy of fundamental and means objectives
        ii) Influence diagrams
    c) Ecosystem types
    d) Categories of actions
7) Workbook
    a) Guide for subregional breakout groups
    b) Portfolio and allocation template
8) Glossary
9) Appendix
    a) Essential preparatory readings
        i) Dept. of Interior's SDM Fact Sheet
    b) Prototype development during April 2014 webinars & responses to comments
    c) Detailed comparison of current prototype (mid-May 2014) with 2011 prototype
    d) Map of subregions and segments

Appendix D **Breakout guide used during stakeholder workshop.**

D-1 Developing influence diagrams and measurable attributes

Day 1, Tuesday, 1-3pm

Expected outcome:

1. **For each ecosystem type** (see **section 6c in Info Pack**), draft final ***influence diagram*** (see simplified example below) relating *categories of actions* (see **section 6d in Info Pack**) and *external drivers* (see Glossary in **section 8 of Info Pack**) to *intermediate drivers, constraints,* and *fundamental objectives* (see **section 6b in Info Pack**). Diagram should be in a format that the subregional team leader can present during plenary.
2. ***Measurable attribute*** (metric) **for each factor** (i.e., box) in each influence diagram.

Why is this important? These influence diagrams and measurable attributes will be incorporated into a *decision model* that will be used to identify *optimal allocations* of conservation funding within each of the four subregions of SF Bay. The decision model will be populated by participant input, and the results will be presented at the end of the workshop. During Thursday AM breakout, the group will make predictions about projected outcomes for each fundamental objective as a function of their drivers (i.e., intermediate and external).

Suggested approach:

Overview

- **Work individually or in pairs** to develop one influence diagram for each ecosystem type (see general example below) and for each *outcome horizon* (2015-2029 & 2030-2100), with a measurable attribute (metric) for each factor in the diagrams.
- You may use flip charts, colored sticky notes and/or masking tape to construct your influence diagrams, but please transfer these into a computerized version for presenting during plenary.
- To ensure completion of the elicitation exercise on Thursday AM, **include no more than 20 unique factors** for the entire subregion across ecosystems (factors = fundamental objectives, constraints, external drivers, and intermediate drivers; i.e. not counting the categories of actions).
- To maintain this level of simplicity, **include only those drivers with the greatest influence and that have the most uncertainty** in terms of their magnitudes and their effects on other factors.

Steps

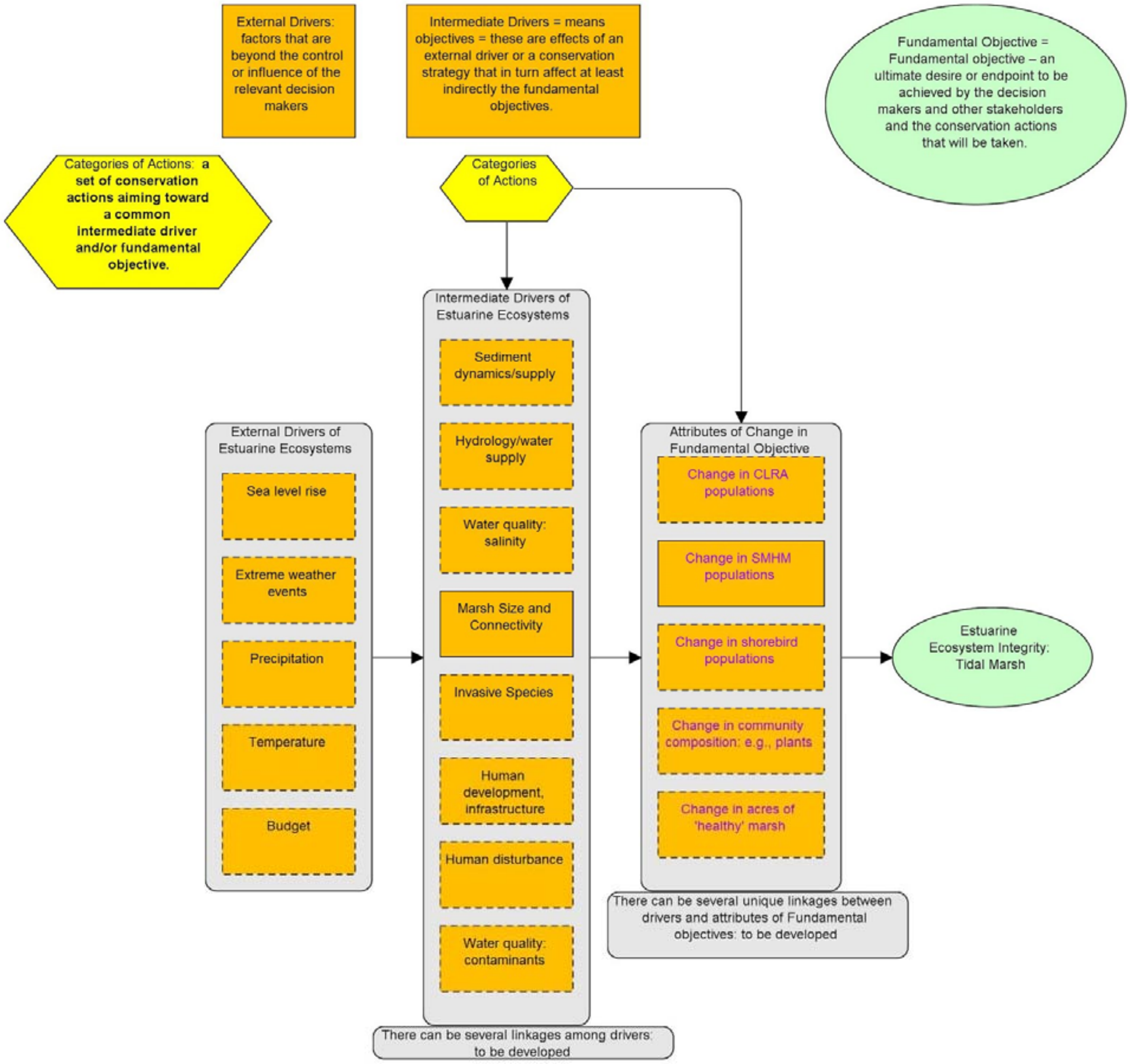
1. Each individual or pair picks one of the four ecosystem types such that all ecosystem types are covered by the breakout group as a whole.
2. For the chosen ecosystem type and for one of the outcome horizons (2015-2029 or 2030-2100), work from the prototype influence diagram to complete the following steps **in 30 minutes**:
    a. Choose up to **5 fundamental objectives and up to 3 constraints** (e.g., endangered species recovery) representing *biotic attributes* of the ecosystem. These selected fundamental objectives and constraints should be of greatest importance to the

decision makers and stakeholders, with an effort to select those that are unique and non-duplicative. For example, including both California clapper rail and black rail may be duplicative. Fundamental objectives and constraints should be on the right-hand side of the influence diagram and have **no arrows coming out of them**. Attributes representing multiple (rather than individual) fundamental objectives and constraints may be used to help simplify the diagram (e.g., index of ecosystem integrity).

b. **Identify three of the intermediate drivers** having the greatest uncertainty and projected impacts on the suite of fundamental objectives and constraints. Intermediate drivers are affected by *external drivers* and/or other intermediate drivers.
c. **Connect each of the three intermediate drivers to fundamental objectives and constraints** that they affect using arrows.
d. **Identify three of the *external drivers*** having the greatest uncertainty and projected impacts on intermediate drivers and/or (directly) on fundamental objectives and constraints. External drivers are those beyond the control of management and have no arrows coming into them (e.g., sea level rise, extreme storm events, availability of conservation funding, policies enacted by upper government levels).
e. **Connect each of the three external drivers** to intermediate drivers, fundamental objectives, and/or constraints that they affect using arrows.
f. **Assign a measurable attribute to each factor** (i.e., external drivers, intermediate drivers, and fundamental objectives) in the influence diagram (can use same ones for both outcome horizons).

3. Discuss the influence diagram (from step #2) with the entire breakout group and revise if needed (**30 minutes**).
4. Repeat steps 2 & 3 for the other outcome horizon.

Prototype influence diagram to be customized for particular ecosystems within subregions:



D-2 Developing future scenarios and allocation options

Day 2, Wednesday, 9:20 - 11:30am

Expected outcomes:
These will be presented by the subregional team leaders during plenary.

1. **Alternative environmental scenarios**: two scenarios for each of the near-term *outcome horizon* (2015-2029) and two scenarios for the long-term outcome horizon (2030-2100). Scenarios will represent potential magnitudes of 1-2 focal environmental drivers, external or intermediate, that are of particular concern for management decisions because of their potential impacts on the fundamental objectives and the degree of uncertainty surrounding them. Scenarios must specify whether each focal environmental driver is above or below a

quantitative threshold , e.g. >X meters sea-level rise and >Y severe storms per year. Each threshold should represent the level at which resulting biophysical impacts would become severe enough to cause significant concern by stakeholders and decision makers focused on conservation of SF Bay in terms of the fundamental objectives.

2. **Possible subregional funding scenarios** (ranges of dollar amounts) representing total amount of money available to implement conservation actions (i.e., BEHGU recommendations belonging to the categories of actions for CADS). Develop two funding scenarios for near-term (2015-2029) & two for the longer-term (2030-2050) management horizon.
3. **Alternative subregional allocations** of conservation funding -- allocations should correspond with the best and worst cases under the combination of external-driver scenarios and funding scenarios (#1 and #2 above). An allocation is the percent of funding that would be spent on a particular action category within an ecosystem in each subregion to achieve fundamental objectives. Develop two allocations for near-term (2015-2029) and two for longer-term management horizon (2030-2050).

Why is this important? The decision analysis on Thursday AM will evaluate which of the alternative subregional allocations is optimal for the near-term management horizon (2015-2029), taking into account uncertainties about available funding, environmental drivers, and decisions during the longer-term management horizon (2030-2050).

Suggested approach:

1. Alternative external-driver scenarios -- in each outcome horizon, develop a best and worse-case scenario for a set of environmental drivers (e.g., related to climate change).
2. Possible subregional funding scenarios -- in each management horizon, develop a best and worse-case scenario for funding.
3. Alternative subregional allocations: See attachment "Portfolio and allocation template" and mock example below for the Sierra Nevada. Work individually or in pairs Begin by filling in an "X" for every combination of action category and ecosystem type where dollars could conceivably be allocated for a given external-driver scenario. Then, for a given funding and external-driver scenario, fill in the percentage of dollars that would be spent for each category of actions and/or ecosystem type. If necessary, then allocate those percentages among action categories of among ecosystems for a given ecosystem or action category, respectively.

Mock example alternative allocation for northern subregion of Sierra Nevada:

Subregion: _____*North Sierra*___________________________

Scenario name: ______*Pessimistic*_ _________________________

Outcome horizon (circle one): 2015-2029 OR 2030-2100

Environmental drivers and thresholds: _*< 10 cm avg annual precipitation*__________

Funding level (range of dollars): ____*$10-20 million annually*________________

Action Category	Low Elevation	Mid Elevation	High Elevation
Protect acreage	2	4	12
Manage individual wildlife species	7	2	19
Manage vegetation for multiple species	5	14	4
Manage human disturbance	13	4	14

D-3 Identifying quantitative thresholds and relationships

Day 2, Wednesday, 1:30 - 3:20pm
Expected outcomes:

1. **Quantitative thresholds** for the fundamental objectives and drivers for which thresholds remain to be developed following the Wednesday AM breakout. For each fundamental objective in the influence diagrams, a quantitative threshold should be identified to represent the level at which an outcome would become of significant concern for stakeholders and decision-makers focused on conservation in SF Bay. For each intermediate or external driver, the quantitative threshold should represent the level at which resulting biophysical impacts would become severe enough to cause significant concern by stakeholders and decision makers focused on conservation of SF Bay in terms of the fundamental objectives.
2. **Qualitative relationships** (positive, negative, or unclear) between attributes representing fundamental objectives, drivers, and alternative allocations (see results generated from breakout sessions on Tuesday). Set of qualitative predictions should be in a format that the subregional team leader can present during plenary.

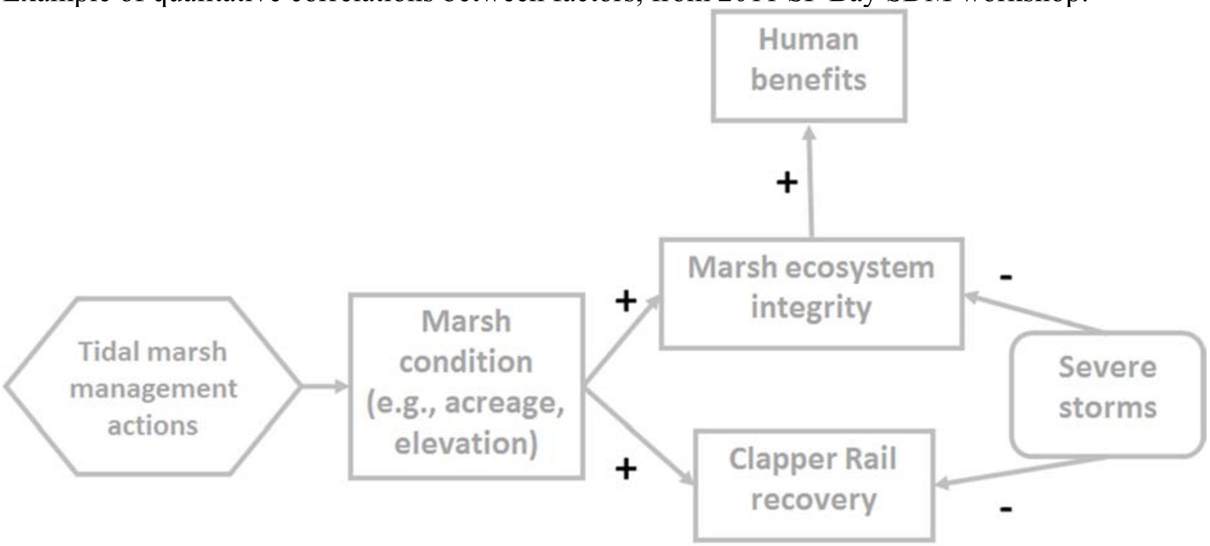
Why is this important? Knowledge about the quantitative thresholds and qualitative relationships between factors in the influence diagram will help ensure logical consistency when populating the decision model with quantitative predictions from participants on Thursday, helping to ensure robust management recommendations that can inform on-ground decisions.

Suggested approach:

1. Quantitative thresholds -- for each fundamental objective and their drivers in the influence diagram, specify a quantitative threshold meeting expectations given above.
2. Qualitative correlations--for each arrow in the ecosystem-specific influence diagrams generated during the Tuesday breakout session, assign a qualitative correlation of positive (+), negative (-), or unclear (?). See example below from 2011 SF Bay SDM workshop.

Examples in other contexts: 1) positive -- we expect a positive correlation between the frequency of intense droughts and the frequency of wildfire in the Sierra Nevada; 2) negative -- we expect a negative correlation between the degree of forest fragmentation and nest survival of ground-nesting forest songbirds; 3) uncertain -- we are unclear, or there is no consensus in the group, about whether carbon storage would increase or decrease with the amount of spring rainfall.

Example of qualitative correlations between factors, from 2011 SF Bay SDM workshop:



D-4 Quantifying predictions and tradeoffs

Day 3, Thursday, 9:15 - 10:45pm
Expected outcomes:

1. **Quantitative predictions** for relationships between attributes representing fundamental objectives, drivers, and alternative strategies (see influence diagram generated from breakout session on Tuesday and set of qualitative predictions from Wednesday PM). Set of quantitative predictions should be in a format that the subregional team leader can present during plenary.
2. **Quantified utility values** for all possible outcomes in terms of the fundamental objectives.

Why is this important? Quantified predictions and utilities are the final essential ingredients to identifying optimal subregional allocations for the near-term management horizon (2015-2029) using a decision analytic approach, taking into account uncertainties about available funding, environmental drivers, decisions during the longer-term management horizon (2030-2050), and trade-offs between medium-term (2030) and long-term (2100) fundamental objectives.

Suggested approach:
Each individual participant enters their predicted probabilities and utilities in the template provided using Excel or Google Sheets. These are then assembled anonymously by the subregional SDM coach and summarized across participants (averages, ranges) for presentation to the subregional

team. Participants may change their numbers during the presentation, and the numbers will be reassembled for the SF Bay-wide decision analysis.

1. **Quantitative predictions --** Hypothetical examples for the Sierra Nevada: 1) if intense droughts occur more than 5 times over the next decade, there is a __% chance that there will be more than 3 wildfires in the Sierra Nevada over the next decade; 2) in forests with a core area of less than 100 hectares, there is a __% chance that the density of ground-nesting forest songbirds will decline over the next decade. In plenary, practice by filling in the blanks and these entries will be discussed as a group.
2. **Quantified utility values --** Hypothetical example for the Sierra Nevada: if there are more than 3 wildfires in the Sierra Nevada over the next decade but ground-nesting forest songbird density has increased over the next decade, the executive director with the Sierra Nevada Conservation Cooperative (fictitious NGO) would assign a utility value of __ out of 100 to this outcome. Here, the best-case (at most 3 wildfires, stable or increasing bird density) would receive automatically a value of 100 and the worst-case (more than 3 wildfires, decreasing bird density) would automatically receive a value of 0. In plenary, practice by filling in the blank and these entries will be discussed as a group.

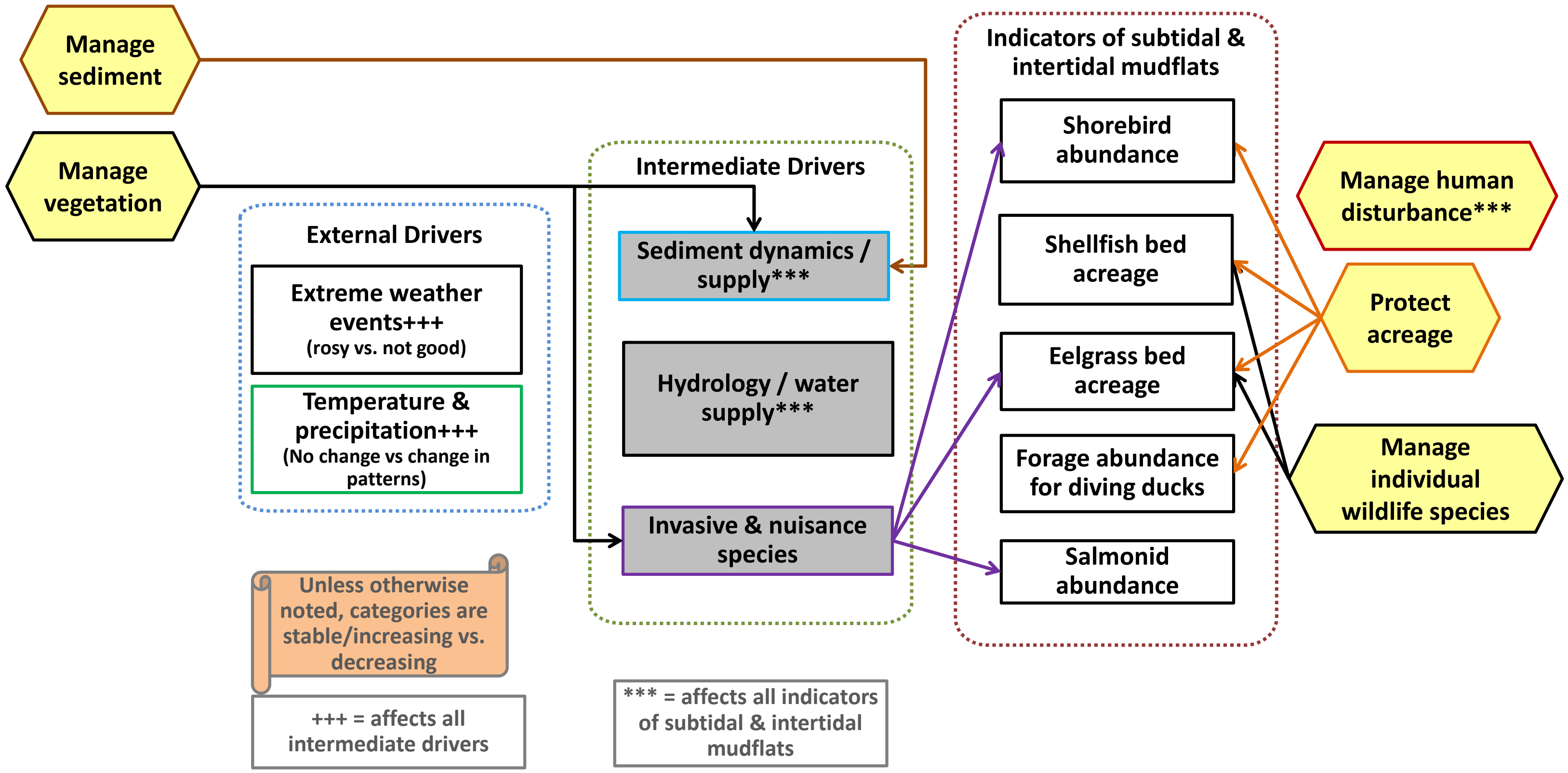
Appendix E **Influence diagrams**

Influence diagrams were completed for North Bay and South Bay representing linkages within near-term (2015-2029) and long-term (2030-2100) portions of their decision tools. For Suisun and Central Bay, only the near-term influence diagrams were completed.

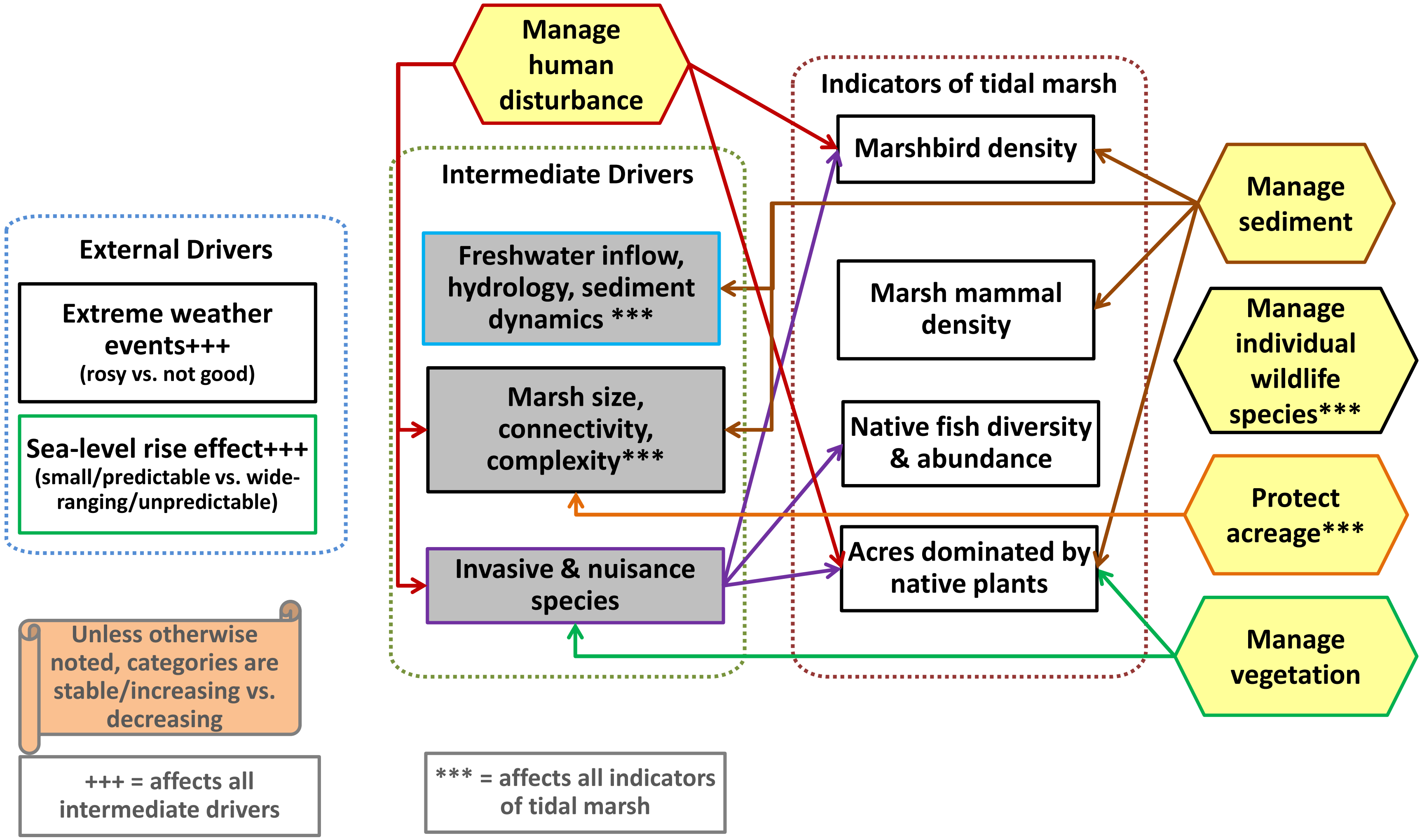
E-1 North Bay

Conservation objectives are shown to the right, intermediate drivers in the middle, external drivers on the left, and action categories around the edges. Implicit intermediate drivers are shaded in gray – these were not included explicitly in the decision tool.

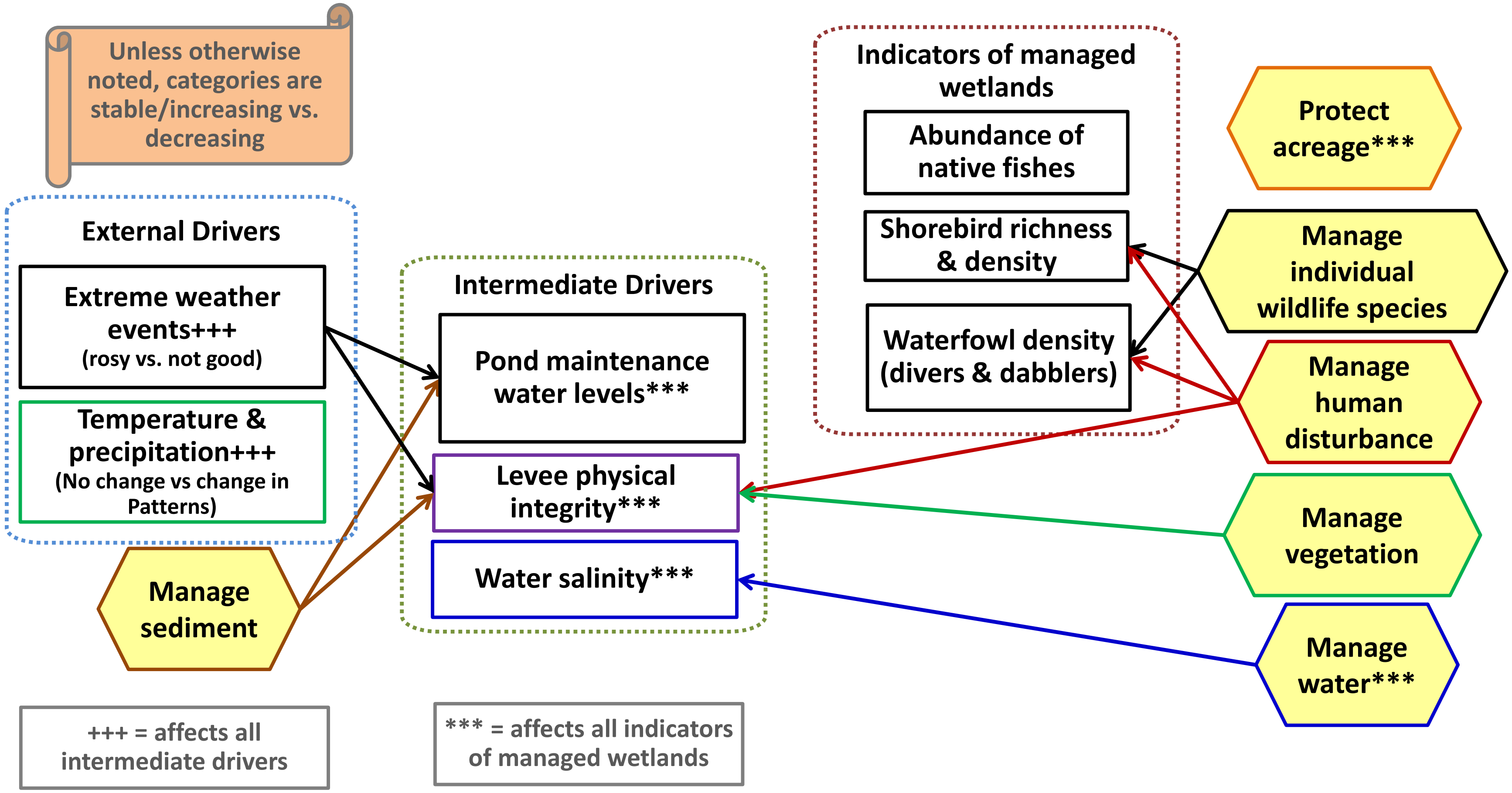
E-1.1 Subtidal and intertidal mudflats, near-term



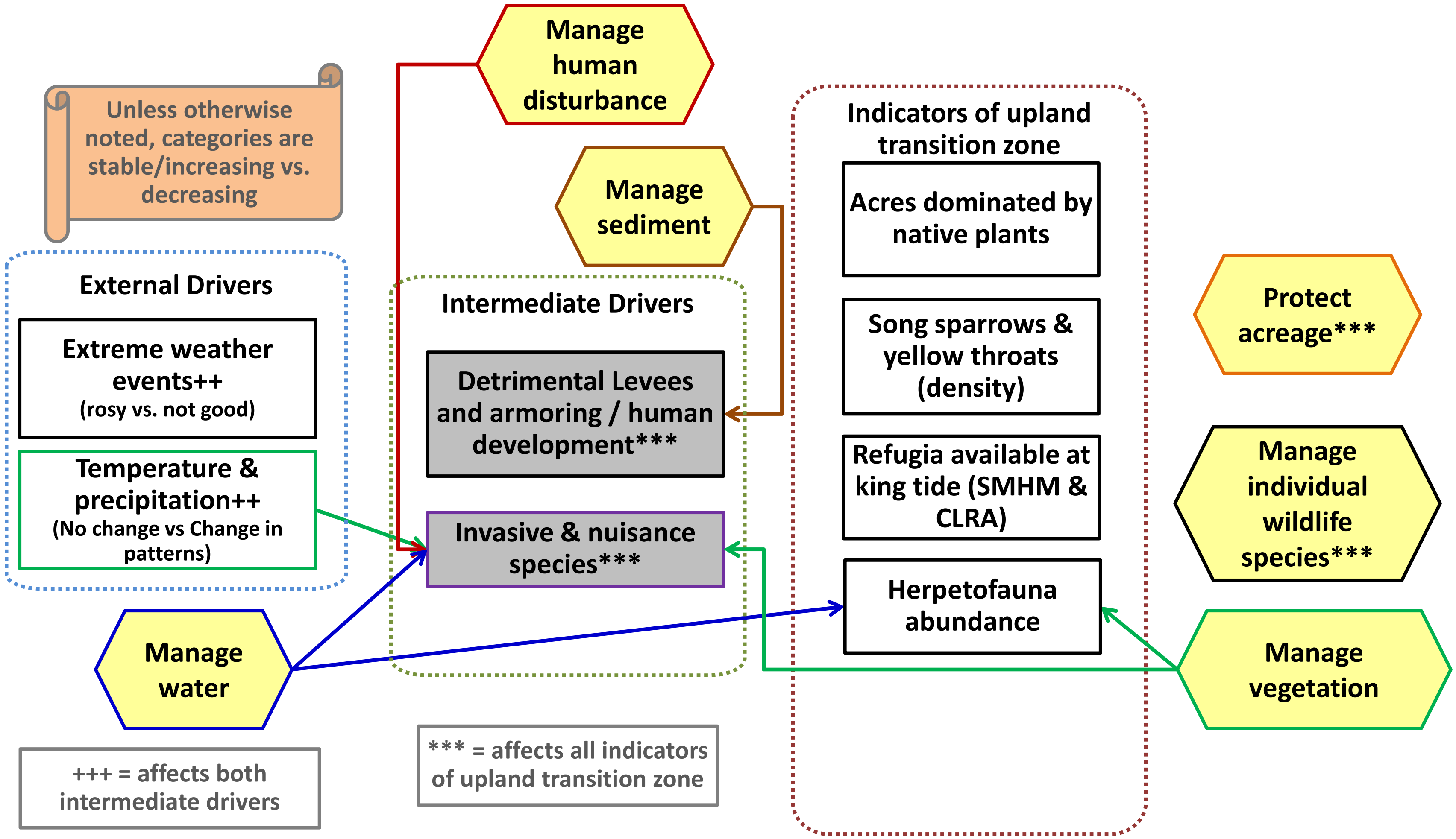
E-1.2 Tidal marsh, near-term



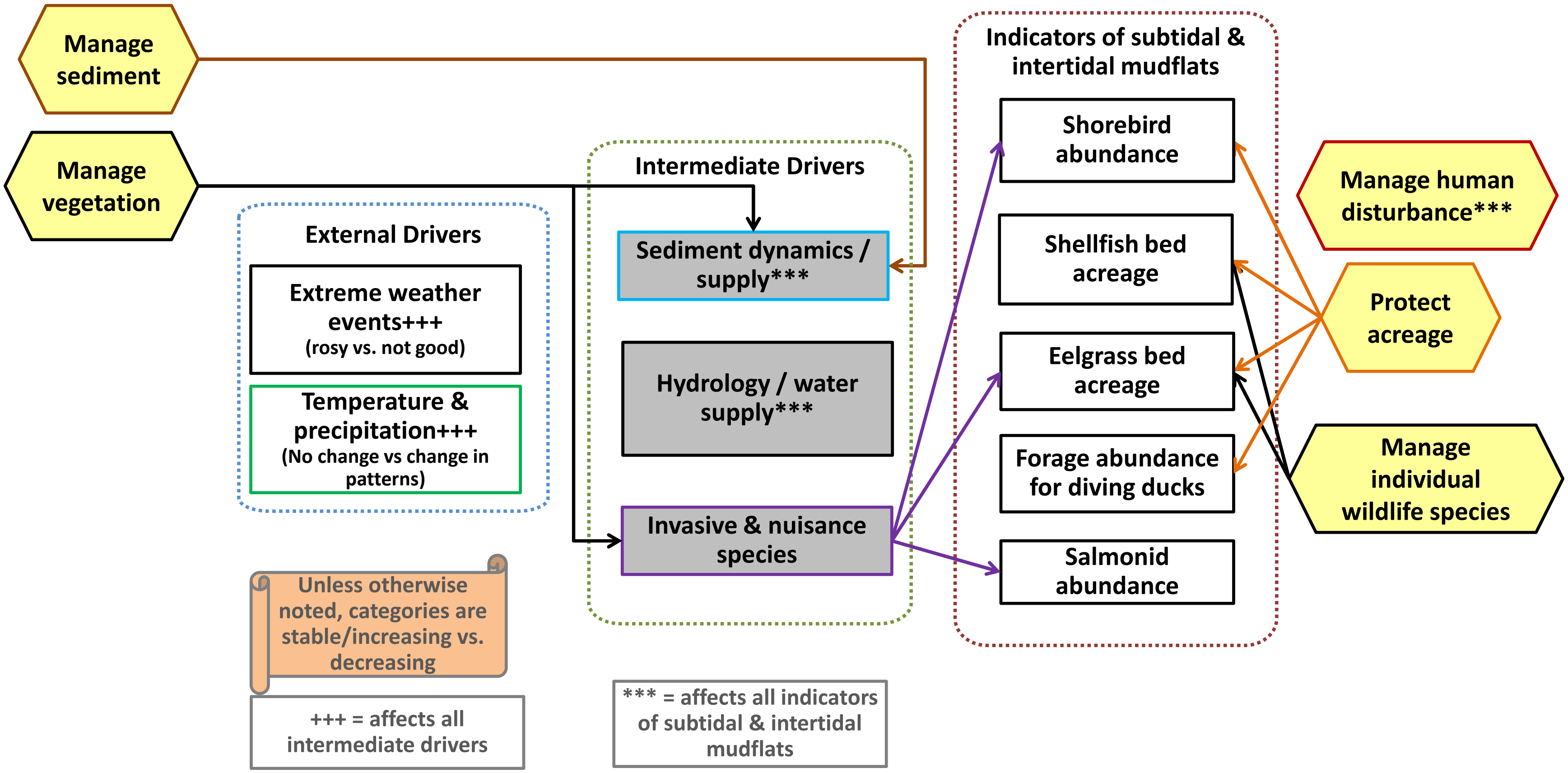
E-1.3 Managed wetland, near-term



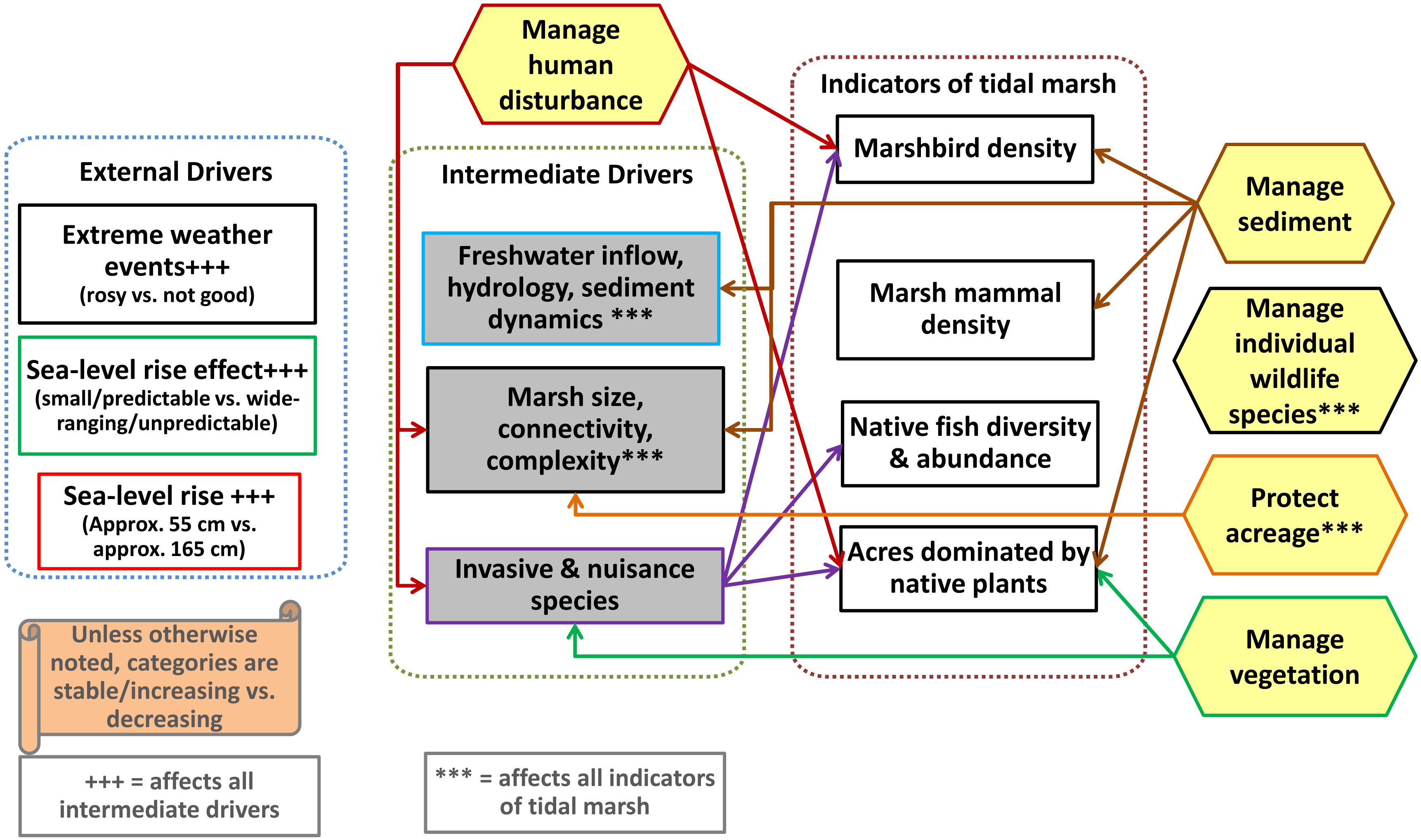
E-1.4 Upland transition zone, near-term



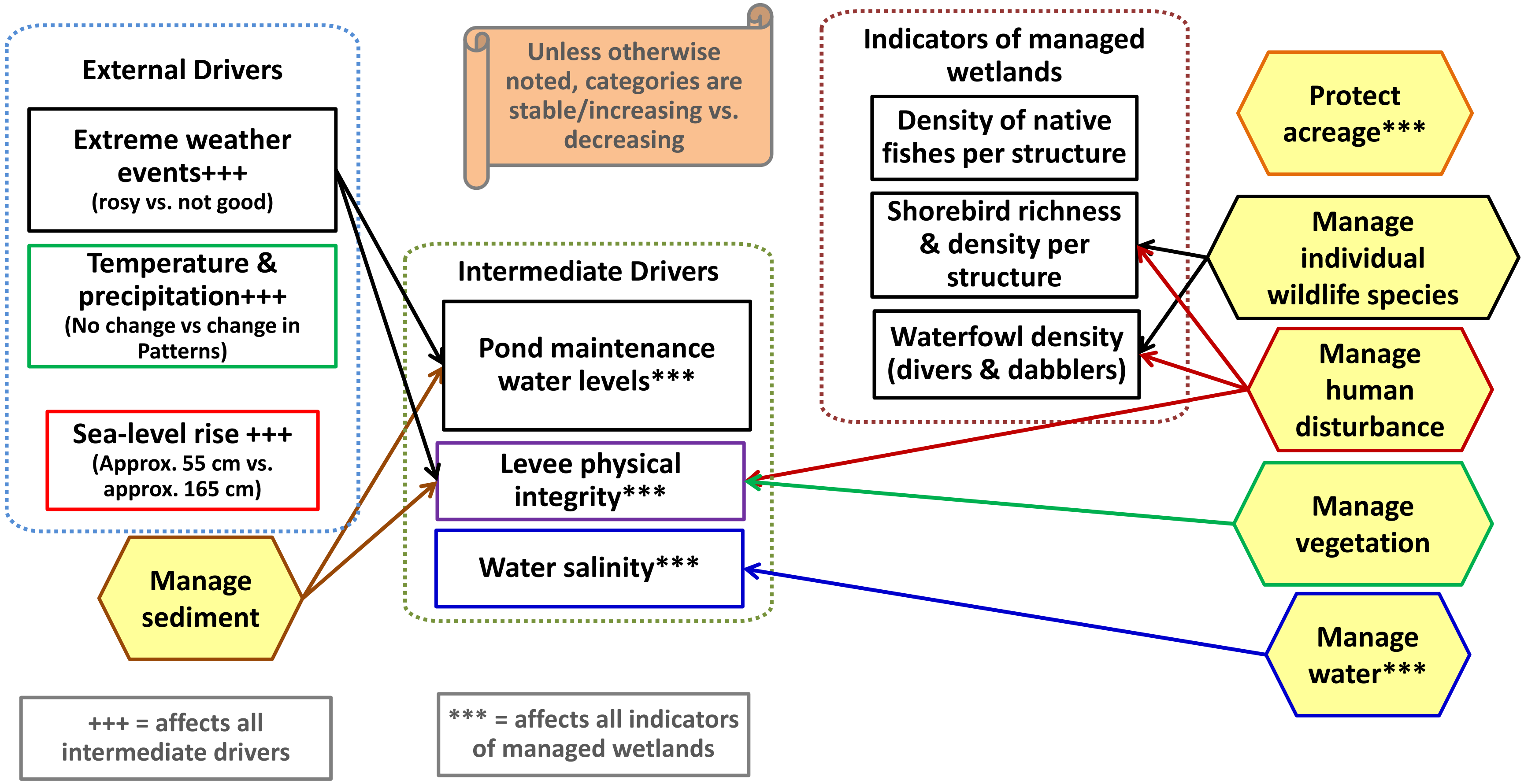
E-1.5 Subtidal and intertidal mudflats, long-term



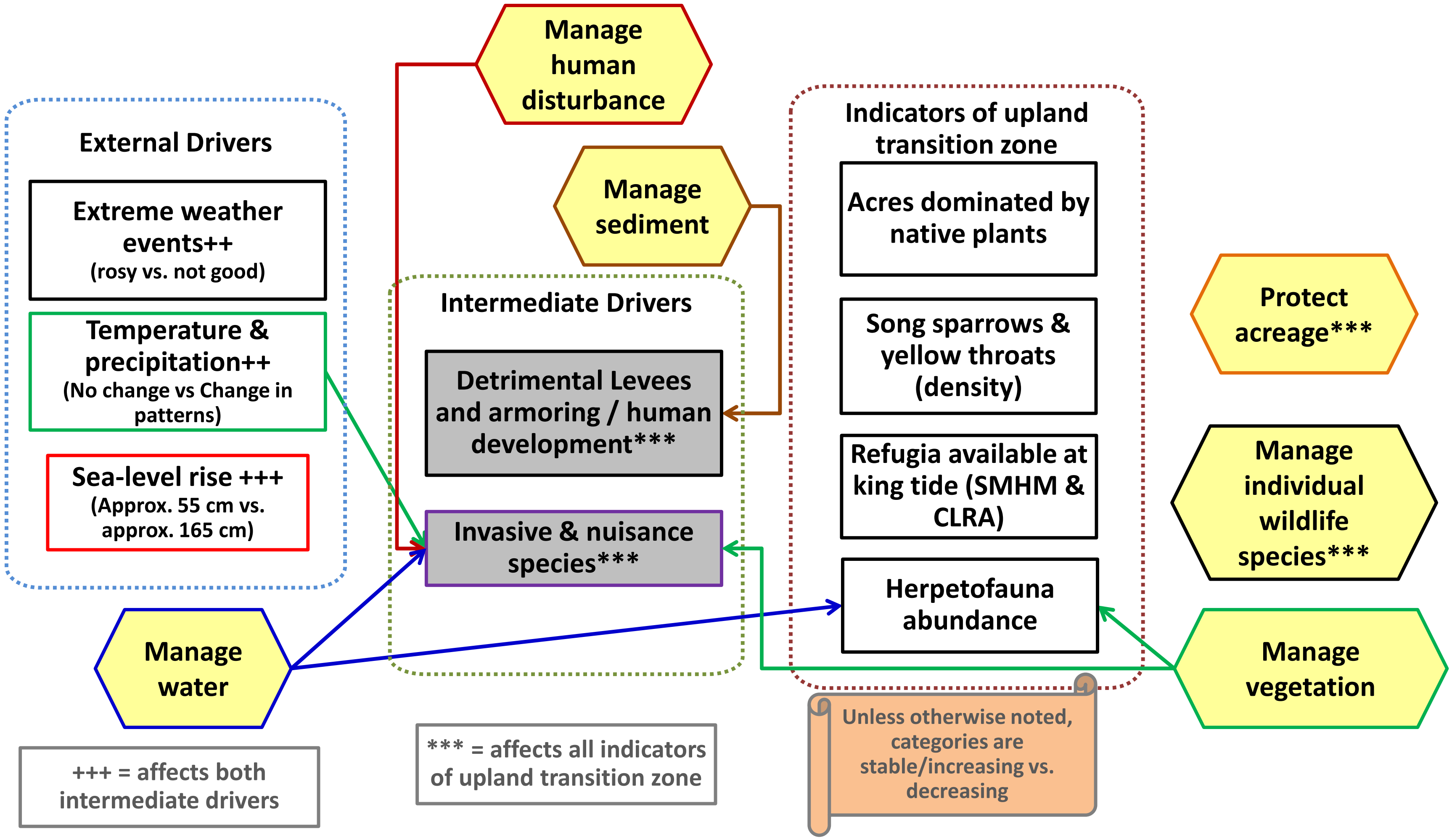
E-1.6 Tidal marsh, long-term



E-1.7 Managed wetlands, long-term

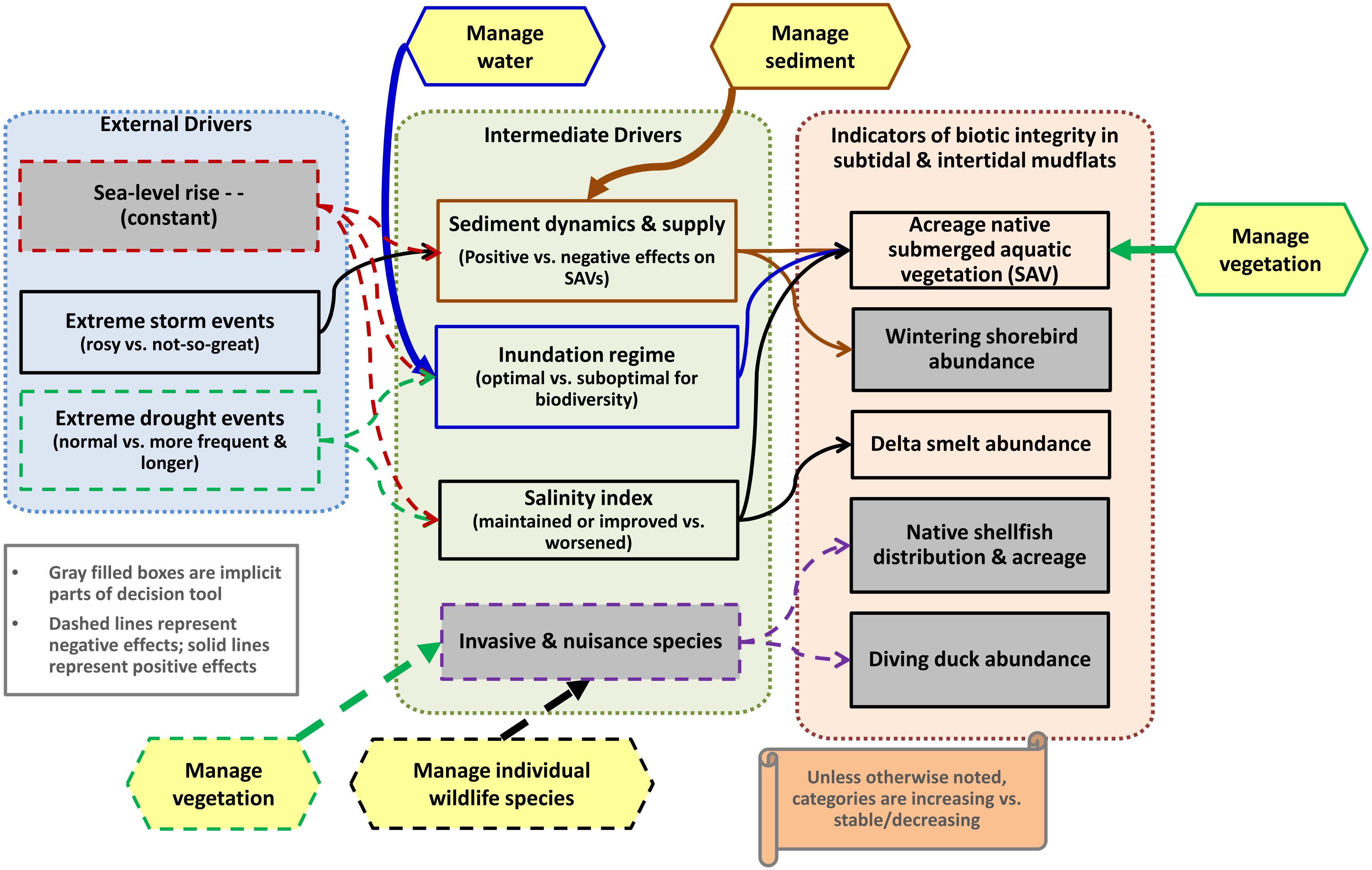


E-1.8 Upland transition zone, long-term

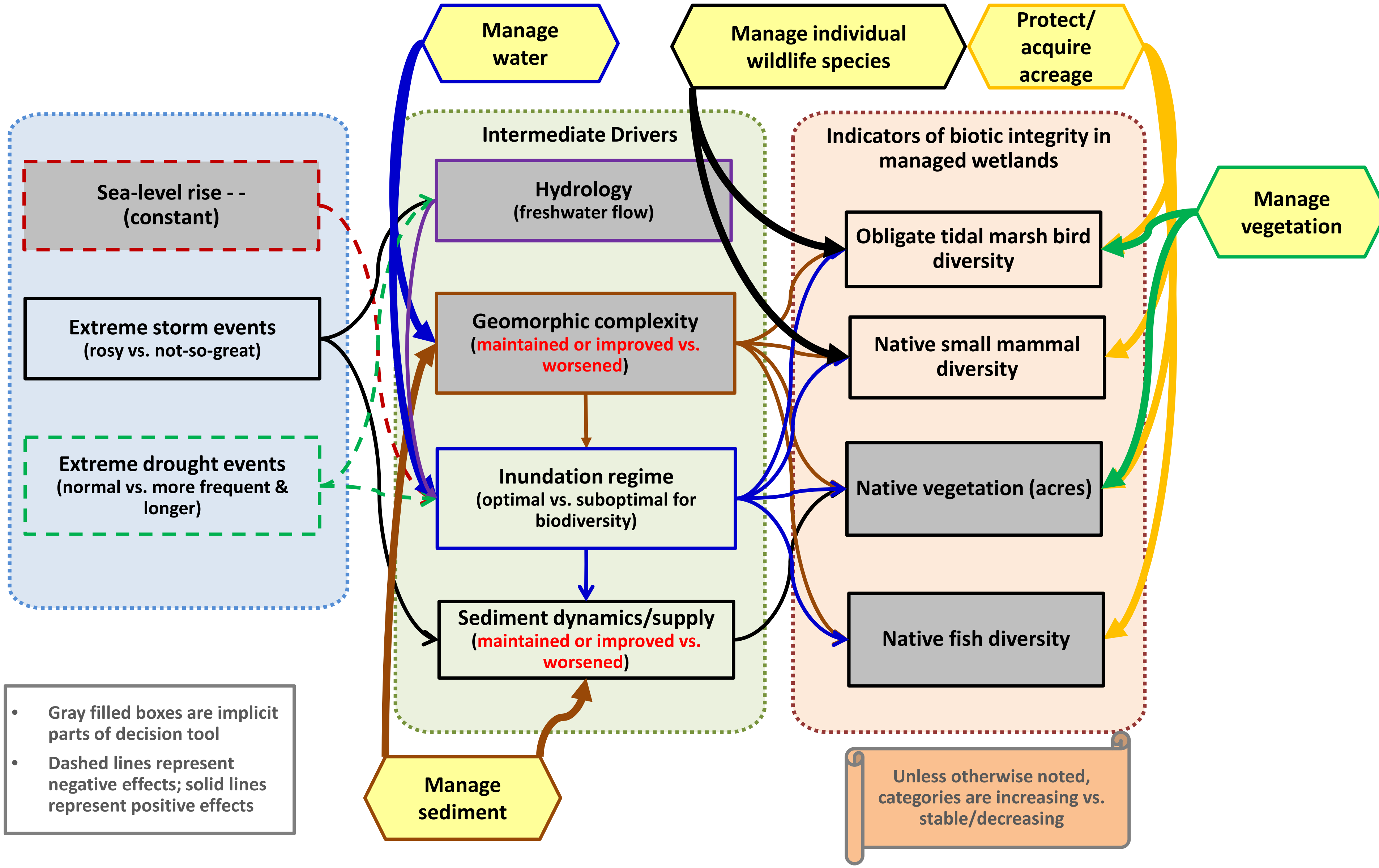


E-2 Suisun

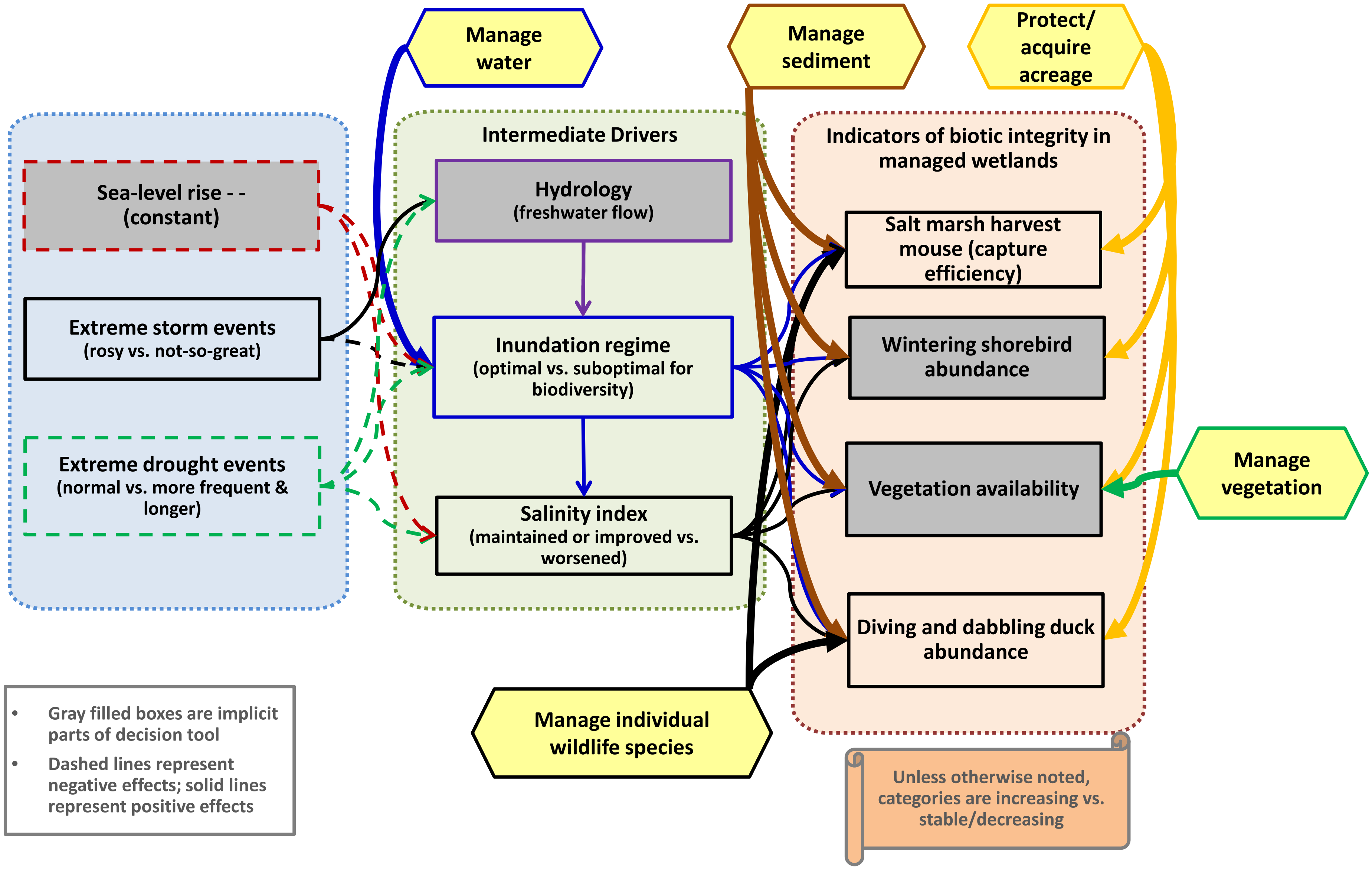
E-2.1 Subtidal and intertidal mudflats, near-term



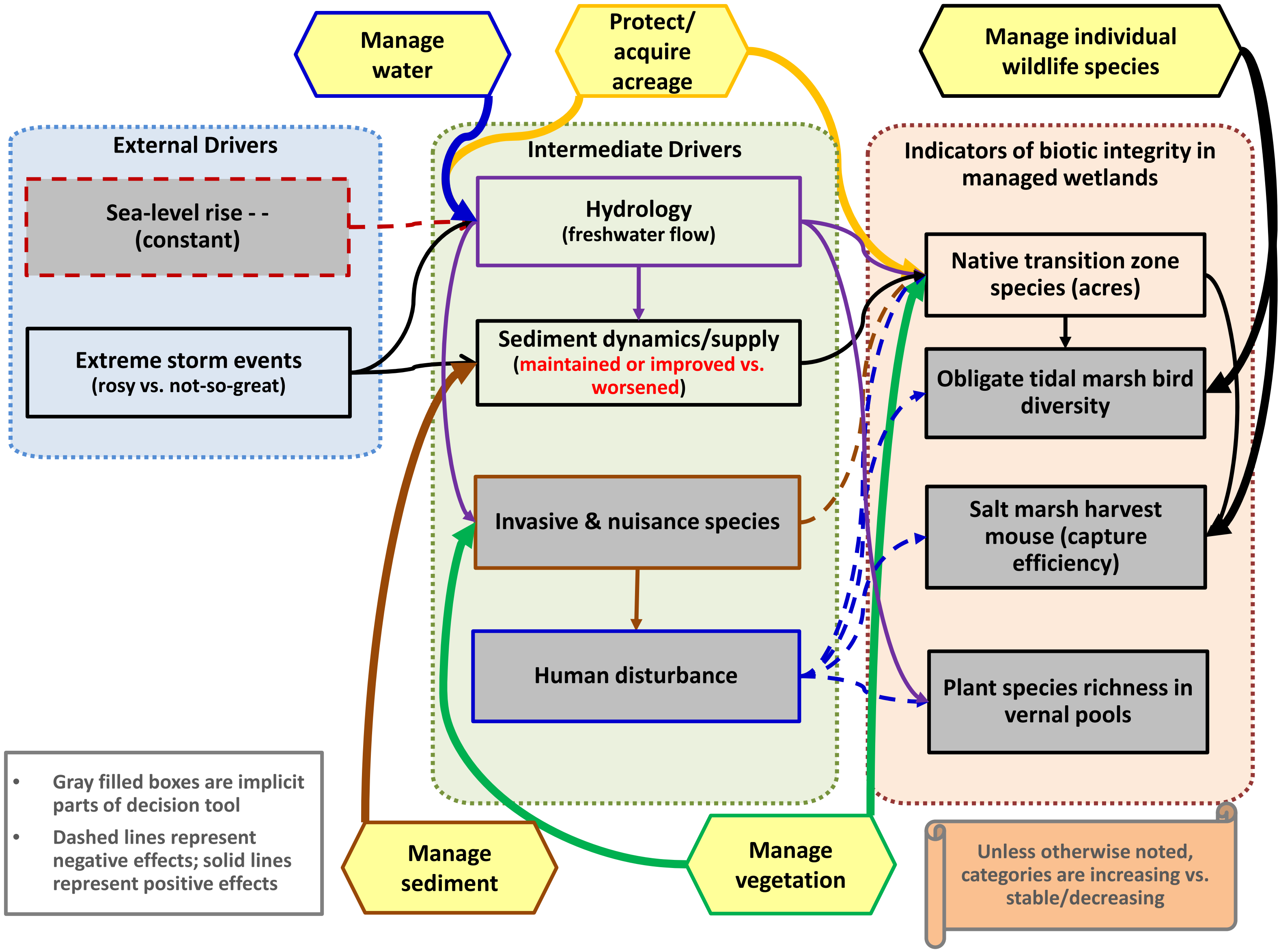
E-2.2 Tidal marsh, near-term



E-2.3 Managed wetland, near-term



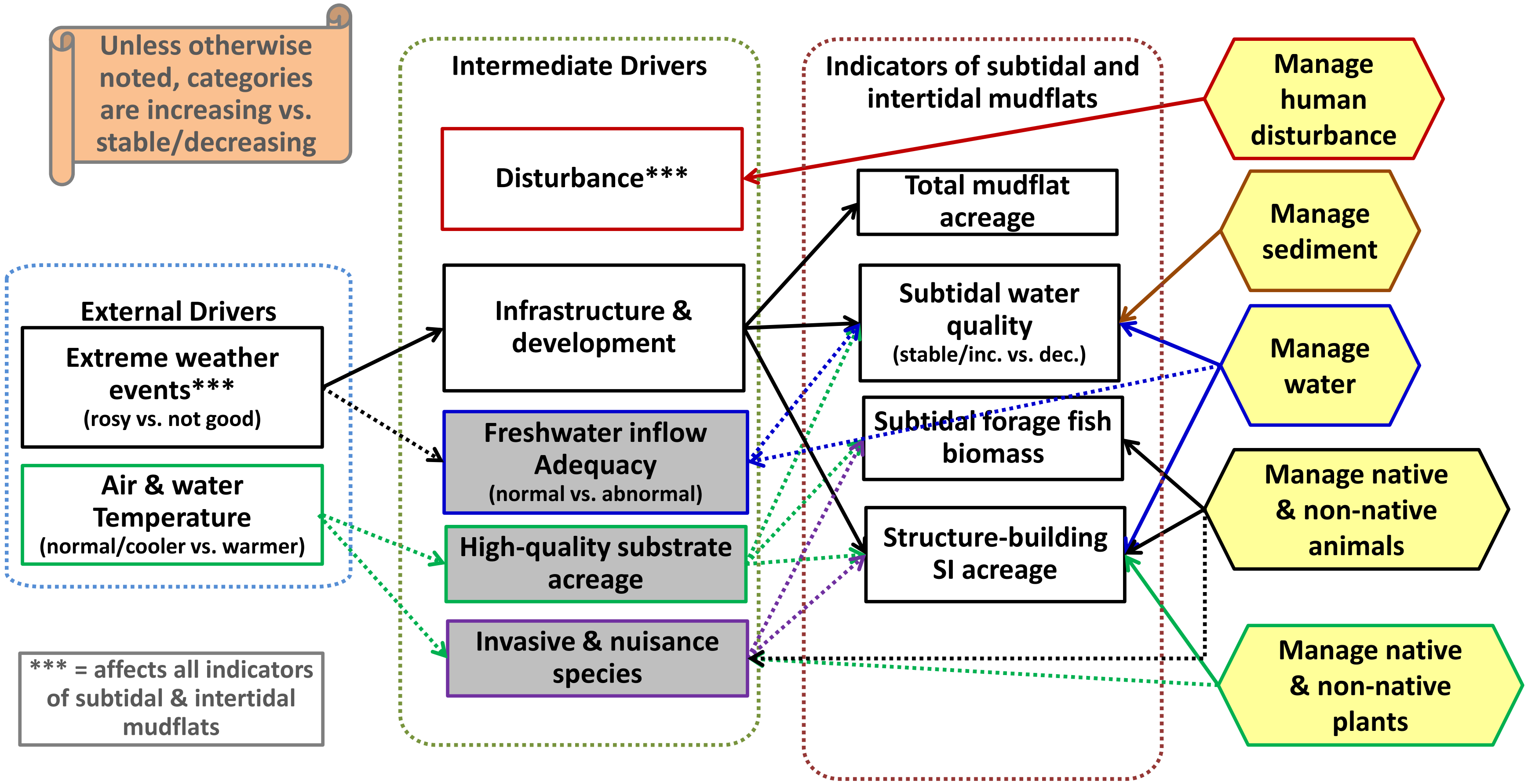
E-2.4 Upland transition zone, near-term



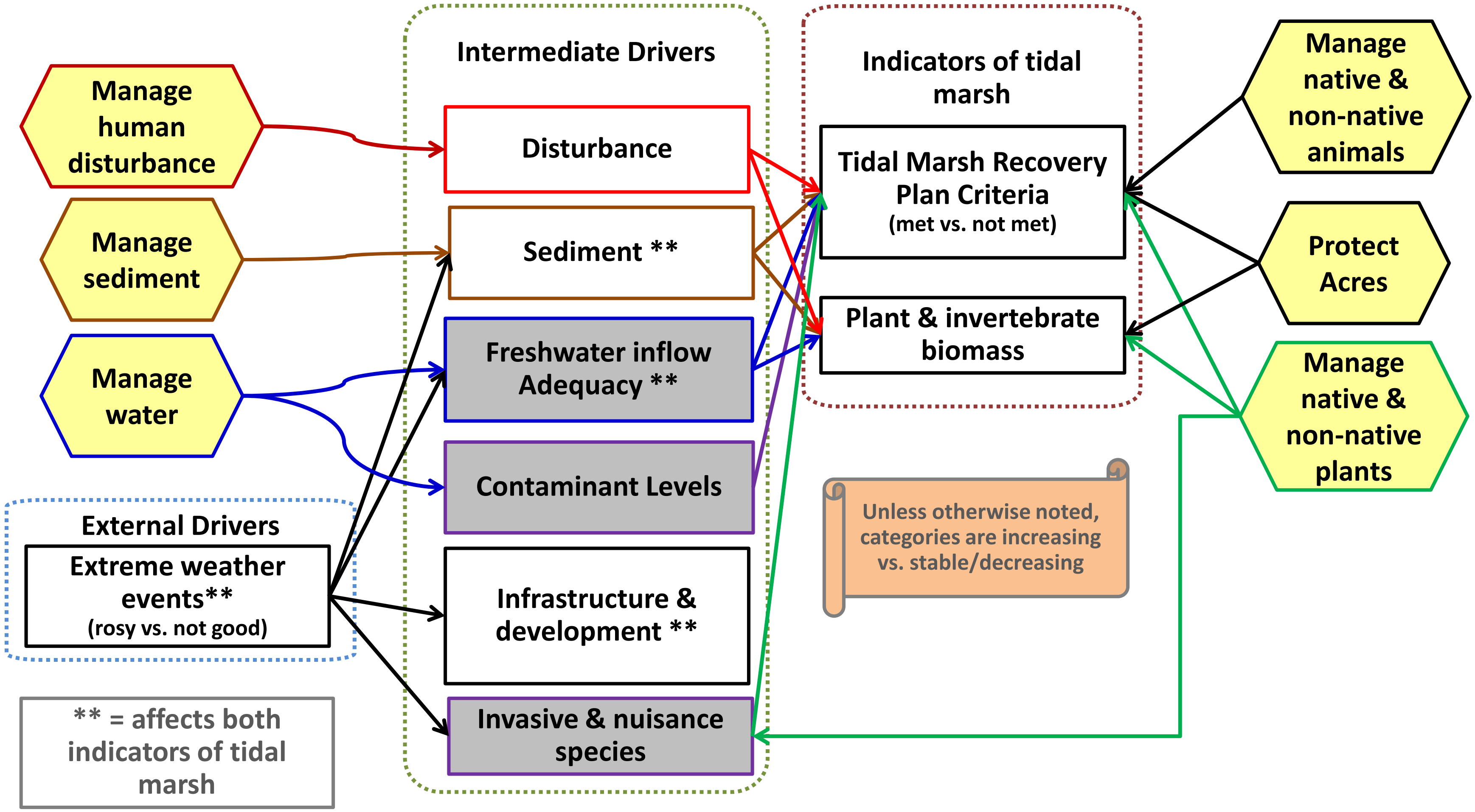
E-3 Central Bay

Colors of lines around boxes and colors of arrows indicate which action category is affecting each factor in the influence diagram. Fundamental objectives are the ultimate desired outcomes of the conservation effort (also referred to as conservation objectives in this report). Two binary levels or categories were assigned to each factor in the influence diagrams, and they are indicated within the diagrams below.

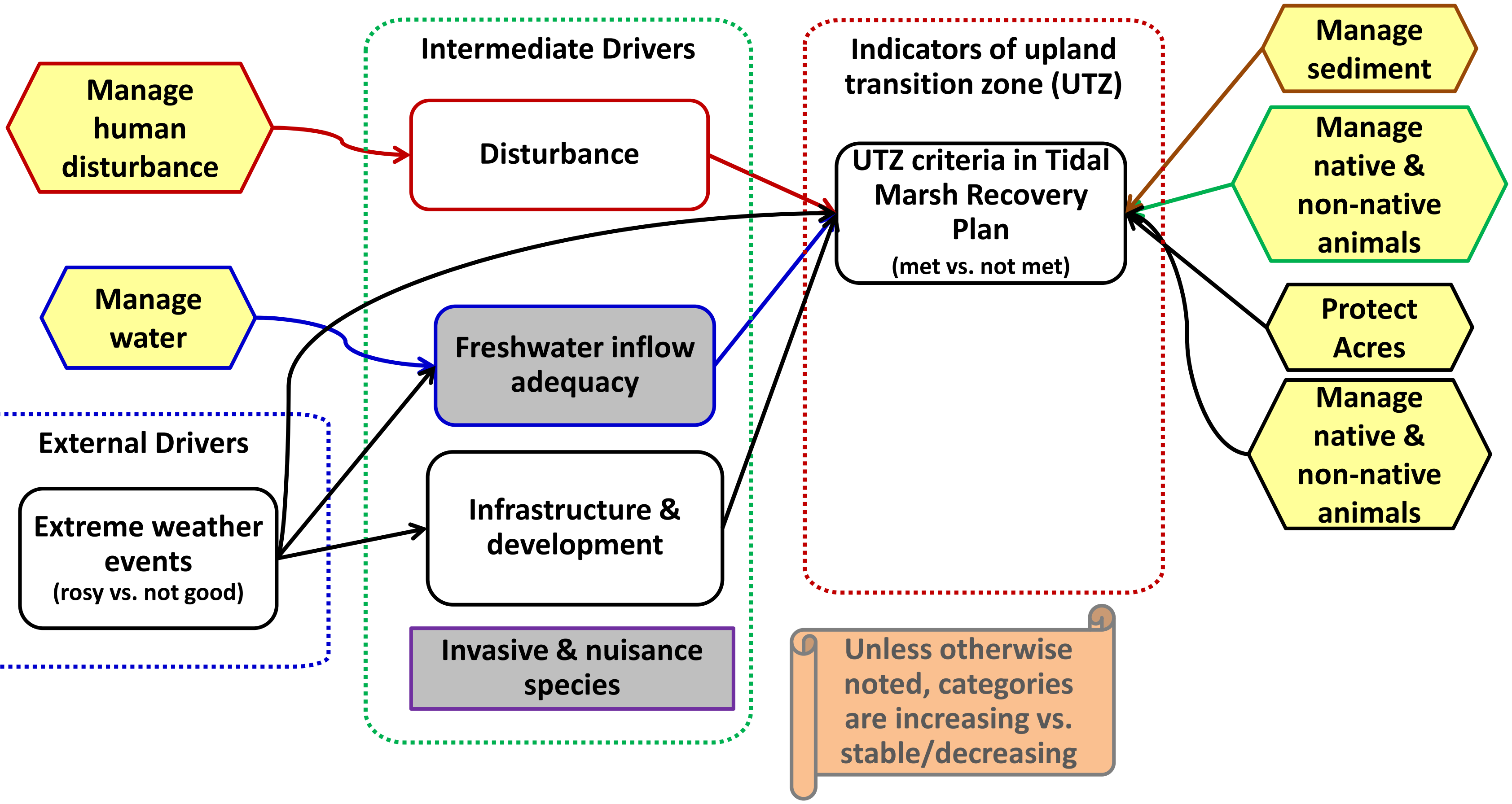
E-3.1 Subtidal and intertidal mudflats, near-term



E-3.2 Tidal marsh, near-term



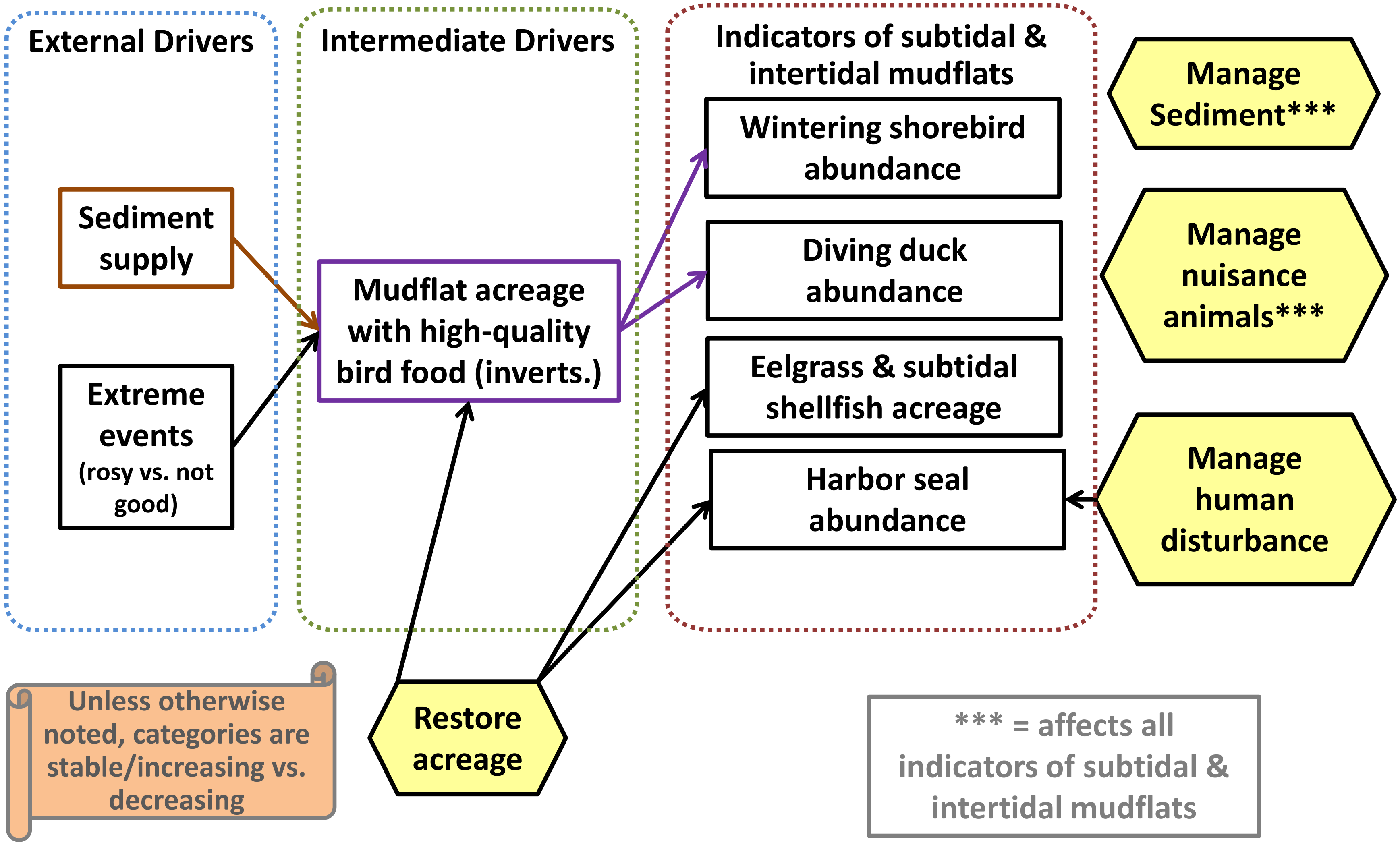
E-3.3 Upland transition zone, near-term



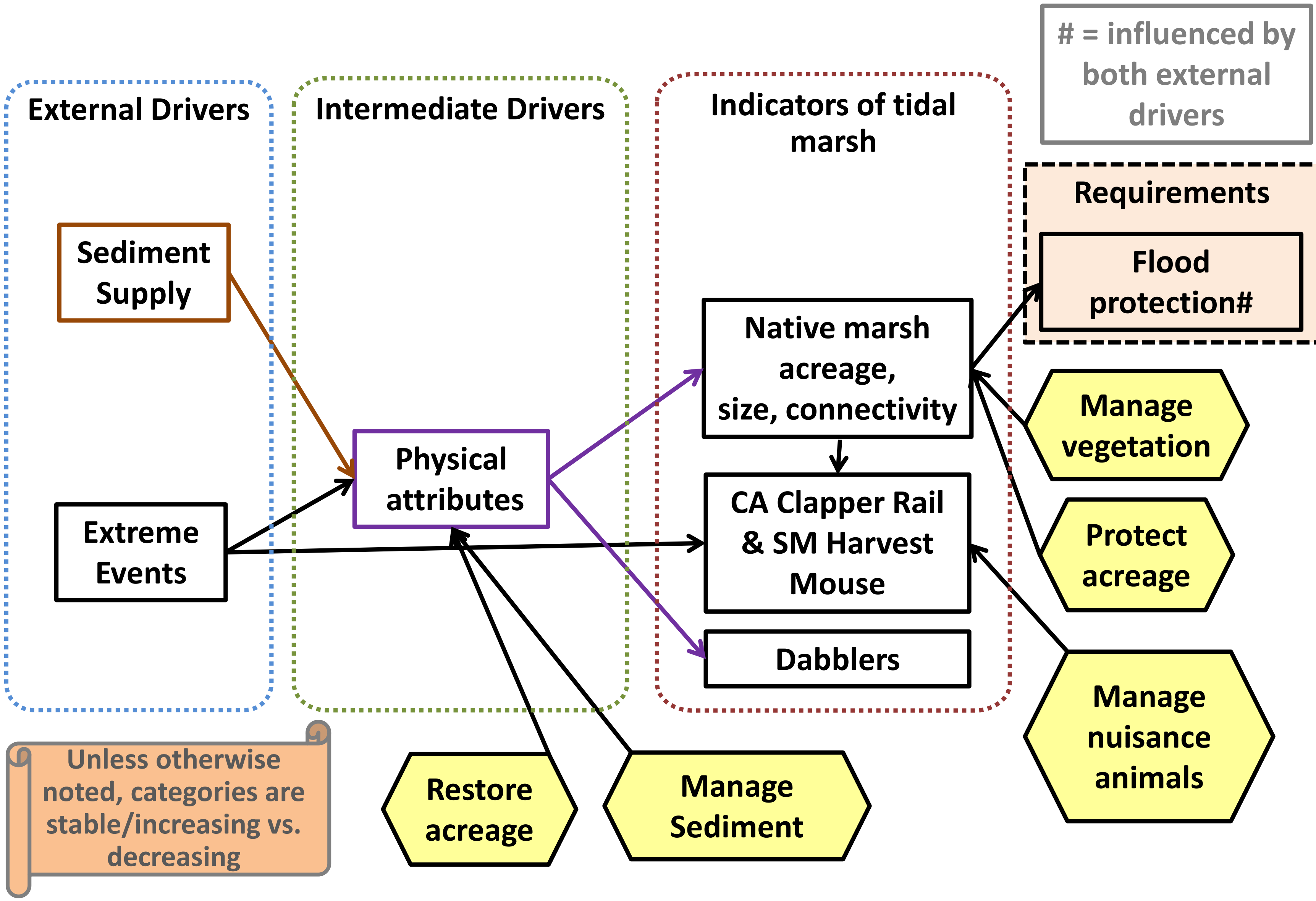
E-4 South Bay

Conservation objectives are shown to the right, intermediate drivers in the middle, external drivers on the left, and action categories around the edges.

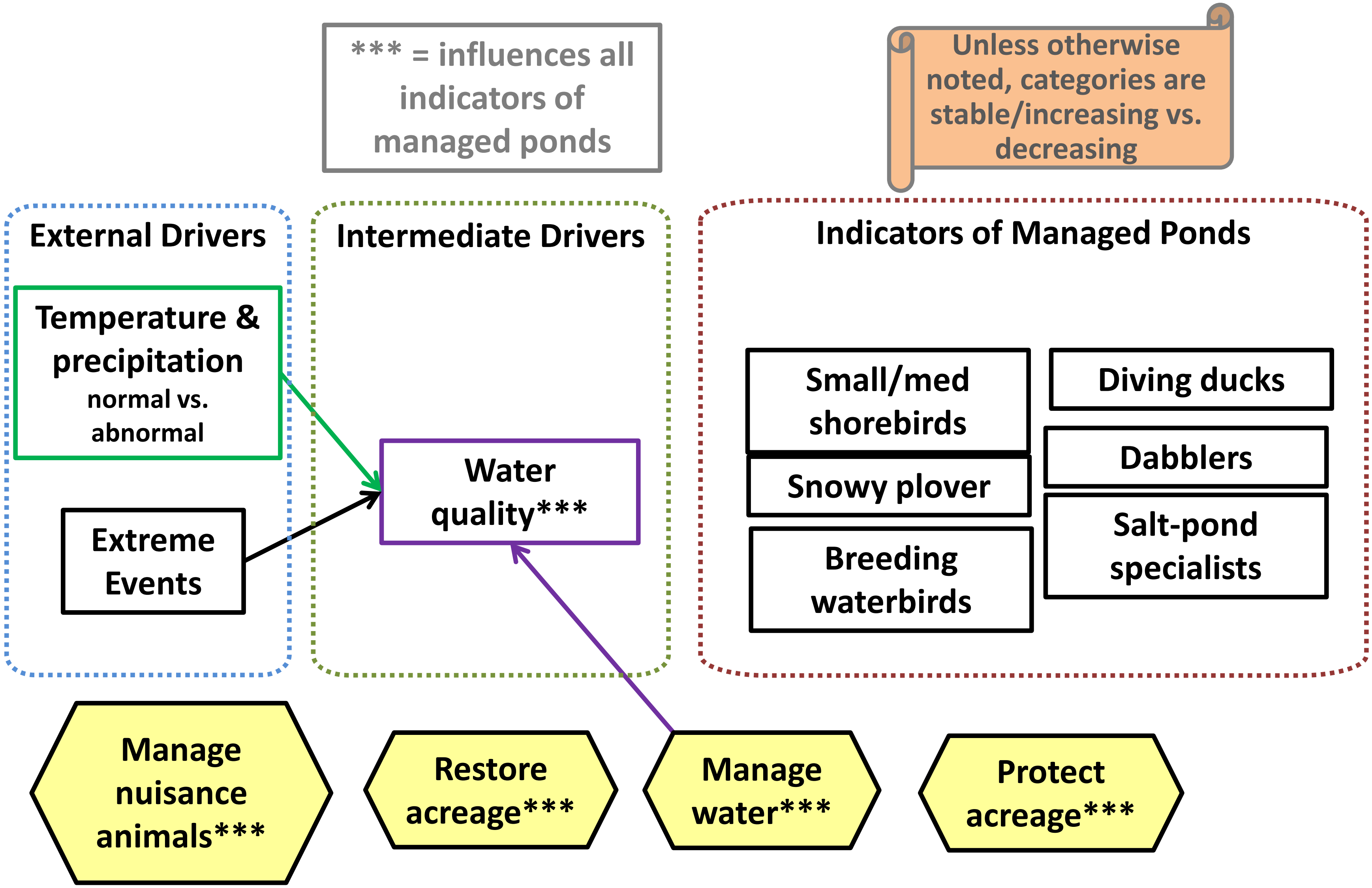
E-4.1 Subtidal and intertidal mudflats, near-term



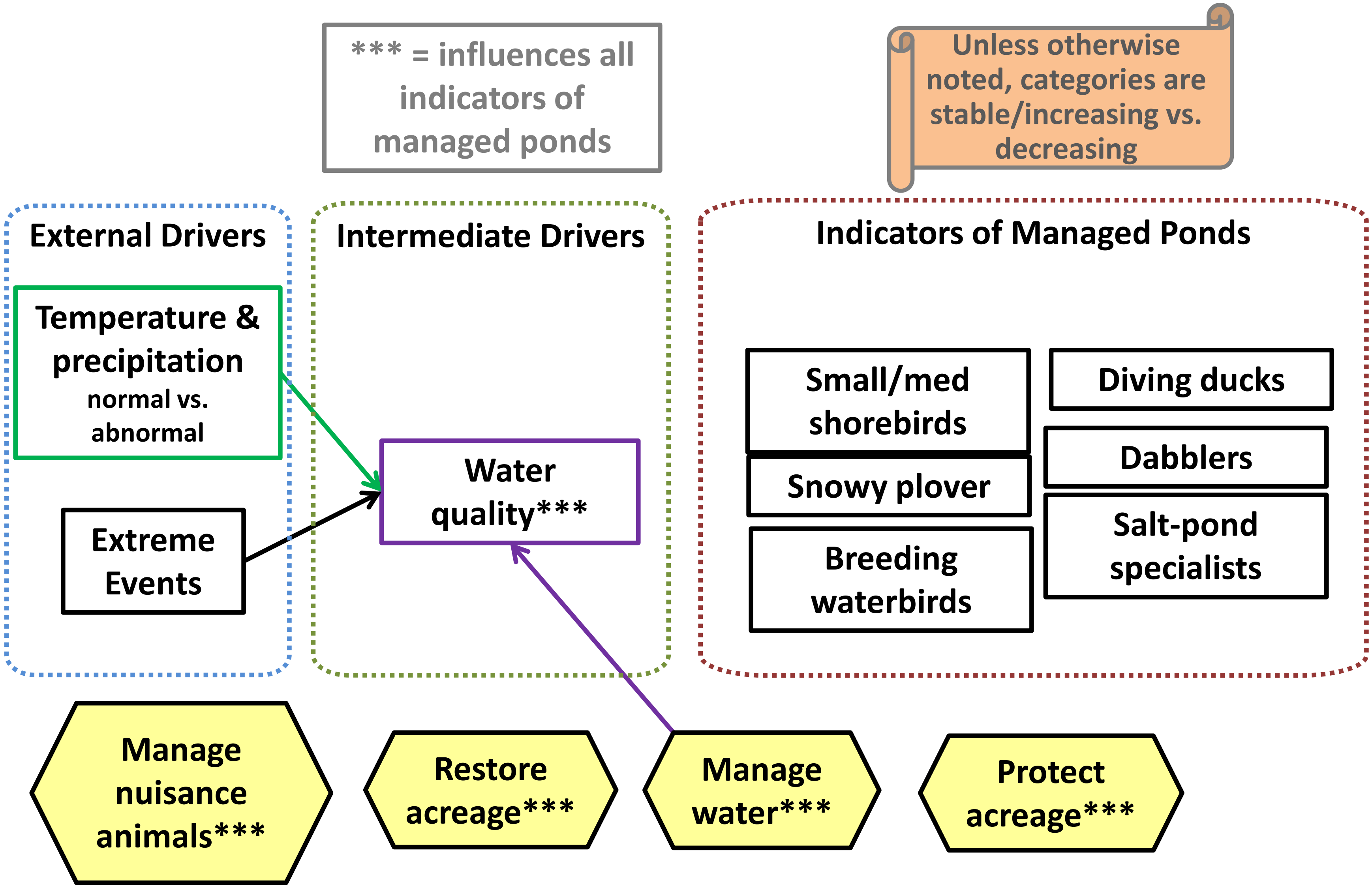
E-4.2 Tidal marsh, near-term



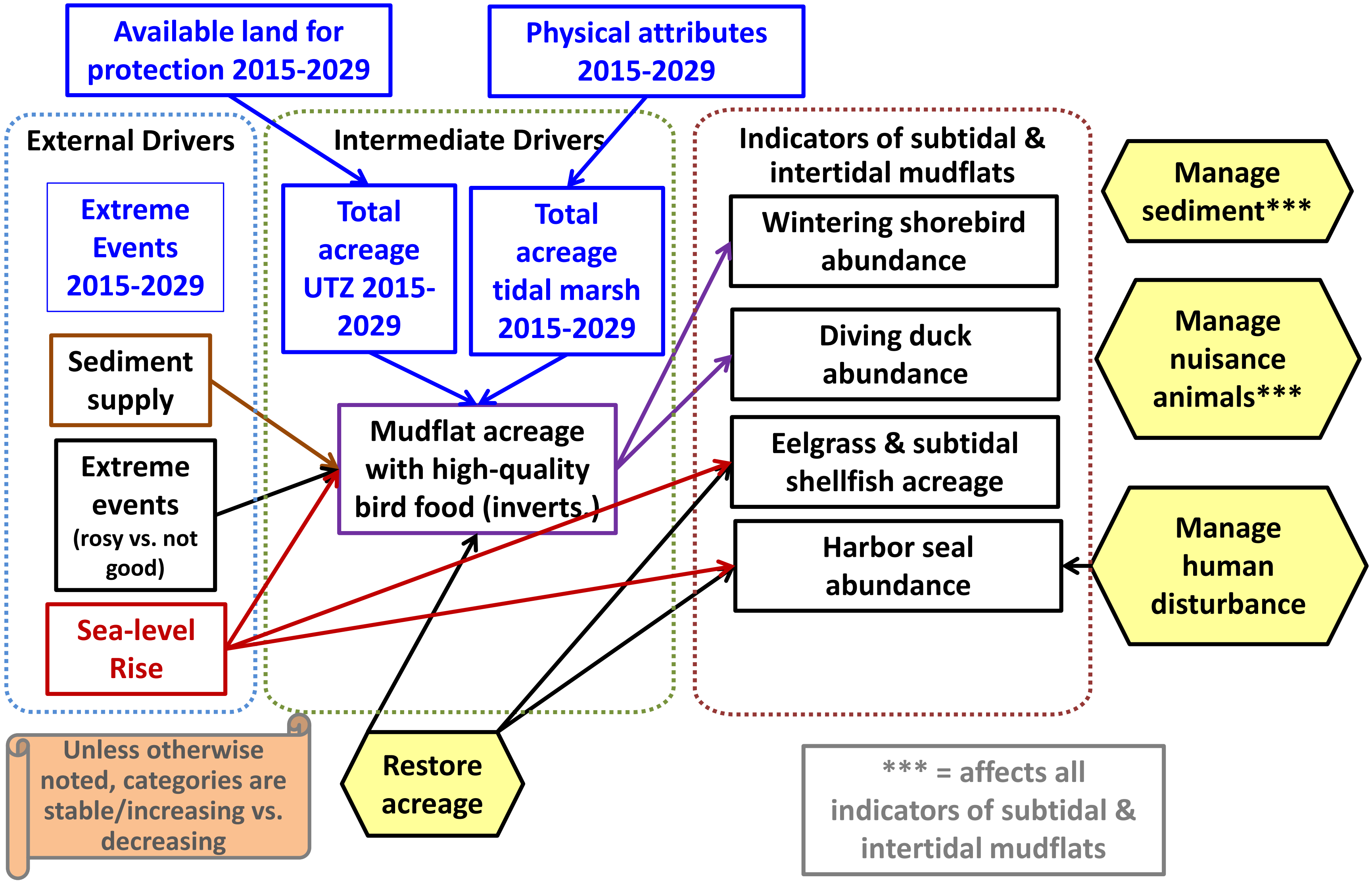
E-4.3 Managed ponds, near-term



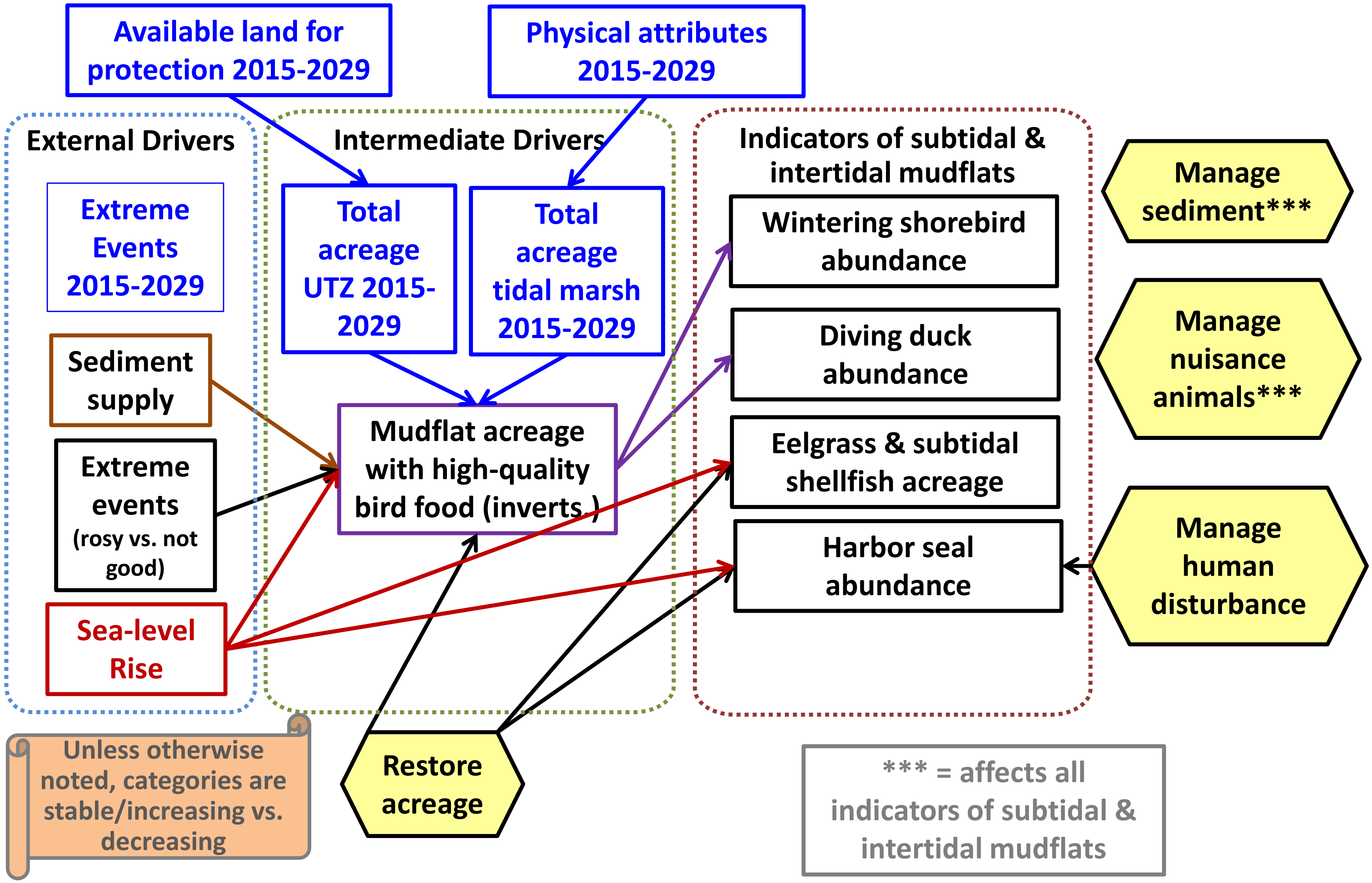
E-4.4 Upland transition zone, near-term



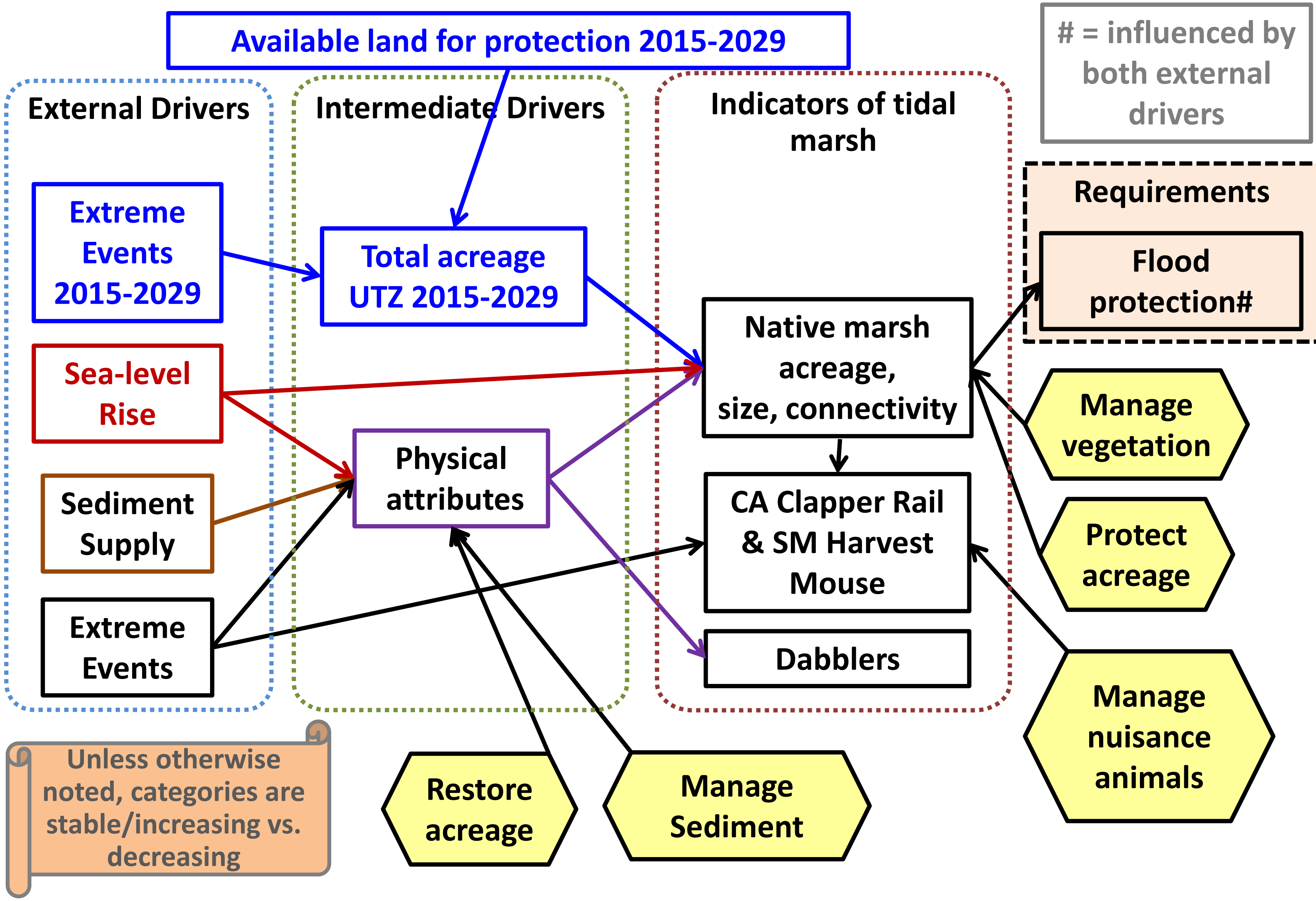
E-4.5 Subtidal and intertidal mudflats, long-term



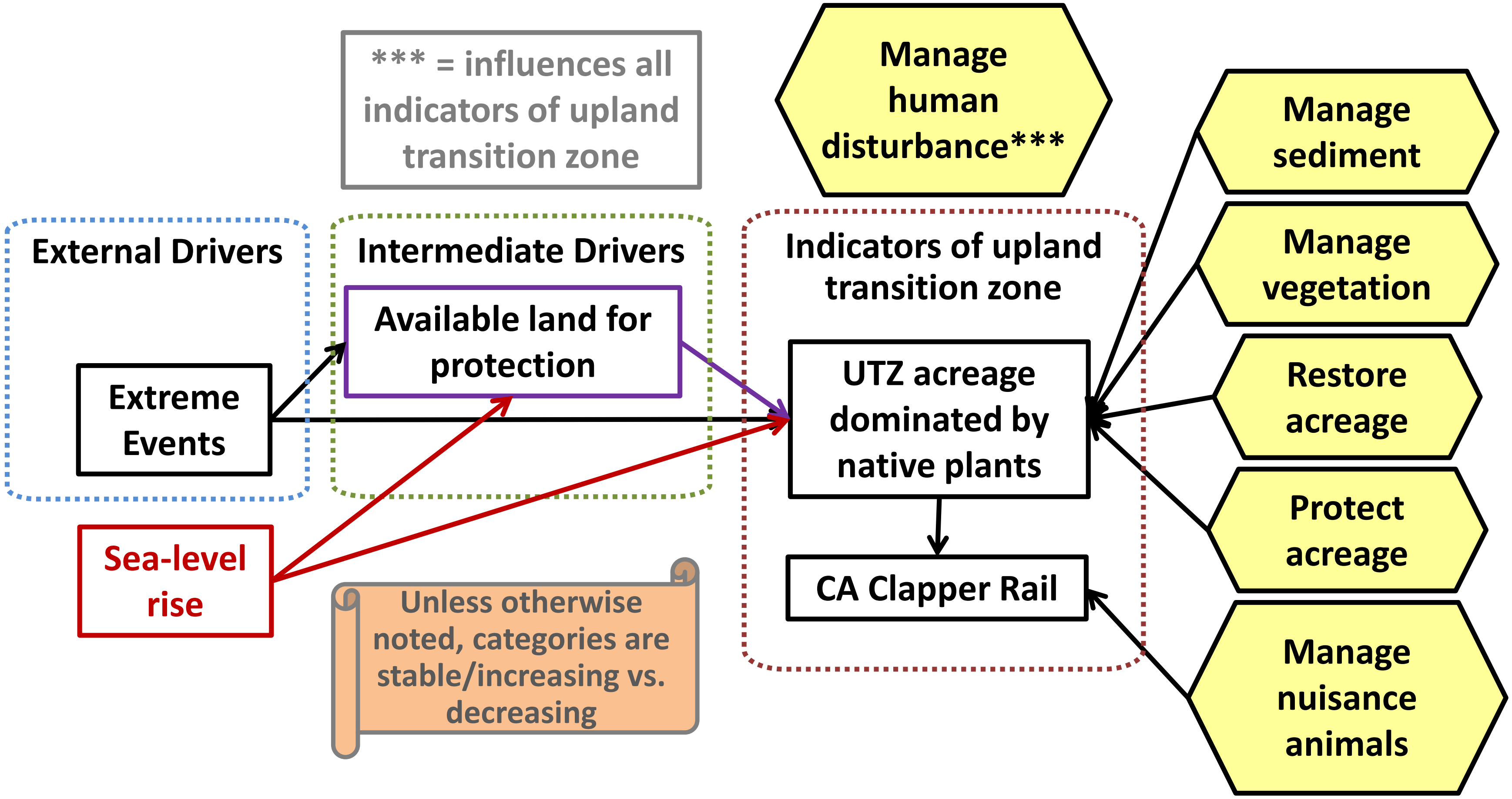
E-4.6 Tidal marsh, long-term



E-4.7 Managed ponds, long-term



E-4.8 Upland transition zone, long-term



Appendix F Descriptions of intermediate drivers for North Bay

This appendix is a companion for section 5.1.5.1.

Intermediate drivers influence indicators of biotic integrity and are themselves influenced by external drivers and/or actions. Team members recognized there are many intermediate drivers that could be included, but to ensure a concise decision model they limited the influence diagrams to the drivers having the greatest uncertainty and greatest potential impacts on the fundamental objectives. Additionally, although these intermediate drivers were included in the influence diagrams, they were not explicitly included in the final decision model. Rather, the team was asked to consider these drivers while providing their expert opinion of how the action categories and external drivers would influence the fundamental attributes.

We identified intermediate drivers in the Upland Transition Zone for each time frame:

Near term (2015-2029):

1. *Detrimental levees and armoring/human development*- this included any sort of human infrastructure that might affect the fundamental attributes. This driver was influenced by extreme events, though the group thought that this could either be a positive or a negative influence, depending on what type of infrastructure is affected and what the desired outcome for that piece of infrastructure is.
2. *Invasive species*- this refers to invasive vegetation, which would be expected to increase in acreage with extreme events, changes in precipitation patterns, and increasing temperature.

Long term (2030-2100):

1. *Detrimental levees and armoring/human development*- this included any sort of human infrastructure that might affect the measurable attributes. This driver was influenced by extreme events and sea level rise (positive), though the group thought that extreme events could either be a positive or a negative influence, depending on what type of infrastructure is affected and what the desired outcome for that piece of infrastructure is.
2. *Sediment supply*- this includes sediment that would be deposited by riverine discharge. It is negatively affected by sea level rise and precipitation, and is affected by extreme weather, though the direction of this effect is uncertain. It positively influences all attributes, and is influenced by managing sediment (including sediment augmentation by dredge material reuse). The supply of sediment in the future will likely be very low.
3. *Adjacent land use for upland transgression*- this represents the type of land that might be available for upland transgression that it is now used for a variety of activities (agriculture, vineyards, etc.). It’s negatively influenced by SLR, and positively influenced by protecting acreage and managing sediment.

For the Diked Wetlands/Managed Ponds ecosystem, the same 3 intermediate drivers were important in both time frames, with the only difference being that SLR will negatively influence each of these drivers in the long term time frame. Additionally, the group acknowledged that many of these structures will not be maintained throughout the long term time frame. They decided to measure the biotic integrity of these as “per structure” so that they can focus on those ponds, etc., that are going to be maintained. Therefore, all intermediate drivers focus on those structures that will be maintained in the future:

1. *Pond maintenance water levels*- this is the managers' ability to maintain the pond at desired water levels, which is negatively influenced by extreme events, and could be positively or negatively influenced by changes in precipitation.
2. *Water quality (salinity)*- this represents the managers' ability to maintain desired salinity levels. Changes in precipitation could either negatively or positively influence this driver, and managing salinity levels would have a positive influence.
3. *Levee physical integrity*- this represents the ability of managers to maintain the levees required for the integrity of pond maintenance intact. This would be negatively influenced by extreme events and precipitation, and managing sediment would positively influence the integrity.

In the Tidal Marsh ecosystem, the group identified 3 intermediate drivers for both time frames, with the only difference being that SLR will negatively influence each of these drivers in the long term time frame:

1. *Freshwater inflow/hydrology/sediment dynamics*- this driver is represented by the maintenance of the marsh plain, and would be negatively affected by extreme events and SLR. This driver would be positively influenced by managing sediment and would have uncertain effects on marsh birds, native fish, and native plants.
2. *Marsh size/connectivity/complexity*- the group suggested that the importance of this driver relies on all three of these attributes of the marsh, but it is measured by acres of marsh. It would be negatively influenced by extreme events, and positively influenced by protecting acreage
3. *Invasives*- this is the same as for the upland transition zone.

In the Estuarine Subtidal and Intertidal Mudflats, the group identified 3 intermediate drivers for both time frames, with the only difference being that SLR will negatively influence each of these drivers in the long term time frame:

1. *Sediment dynamics/supply*- this represents the availability of sediment for this ecosystem, and it would be negatively influenced by extreme events, which would remove sediment, and changes in precipitation, which would reduce sediment supply. Sediment augmentation through re-use, placement, or mudflat protection with living shorelines ("manage sediment") would have a positive effect on this driver.
2. *Hydrology/water supply*- this represents the potential salinity increase in this ecosystem, as influenced by extreme events and precipitation. There is no action currently influencing this driver, though it would have an effect on all attributes, and it is affected by both extreme events and temperature/precipitation.
3. *Invasives*- this is the same as in the other ecosystems, and it would influence shorebird abundance, eelgrass beds, and diving duck populations.

Appendix G Post-workshop elicitation guide

This guide was provided to subregional teams to give them further guidance in providing their probabilities (see section 3.5.3) and utility values (see section 3.6)

G-1 Overview

Expected outcome

Each subregional team member independently fills in their quantitative inputs to their subregional decision model using the spreadsheet template provided by their SDM coach.

Why is this important?

- Quantitative inputs are the **final essential ingredients** to identifying optimal subregional allocations for the near-term management horizon (2015-2029) using a decision analytic approach, taking into account uncertainties about available funding, environmental drivers, and outcomes in terms of the fundamental objectives.
- Collecting and compiling elicited inputs from team members will allow the SDM coaches to **identify an optimal subregional allocation of resources** to maximize SF Bay conservation at the subregional level for this near-term horizon.
- **Draft results** from this near-term horizon decision analysis along with summary statistics for the elicited inputs will be presented to each subregional team for **discussion and input**.
- Following these subregional team discussions, the **subregional decision model will be modified if necessary** and incorporated into a more comprehensive subregional decision model taking into account **decisions during the longer-term management horizon (2030-2050)**, and trade-offs between medium-term (2030) and long-term (2100) fundamental objectives.

Overview of contents within elicitation spreadsheet template

One tab for each element requiring quantitative input for the decision model. Factors can be one of two general types, and the factors were based on influence diagrams developed by subregional teams:

1. *Utility*: values representing all possible outcomes in terms of the fundamental objectives.
2. *Probabilistic (aka stochastic)*: probabilities representing predicted outcomes of alternative allocations, external drivers, and/or intermediate drivers.

G-2 Utilities

Utility values represent how much a stakeholder values a particular outcome in terms of the fundamental objectives. In this case, we're asking them to place a numerical value on how much they value each ecosystem type with regards to its projected change biotic integrity during 2015-2029 on a scale of 0 to 100.

Example: How would you score on a scale of 0-100 a scenario where biotic integrity for subtidal/intertidal flats was ___, tidal marsh was ___, managed ponds was ___, and upland transition zone was ____ . A value of 0 represents the worst-case scenario and great dissatisfaction where biotic integrity is decreasing for all ecosystems; a value of 100 represents the best-case scenario and great satisfaction. A way to think about the scores using a grading analogy is that 100 would be an A+, 90 would be like an A-, 85 a B, 75 a C, etc.

G-3 Probabilities

For each of the probabilistic (aka 'stochastic') factors in the decision model, we need to enter one or more probabilities on a scale from 0-100. Even though a probability is on the same scale as a utility value, a probability has a very different meaning. Whereas a utility represents a stakeholder's happiness or satisfaction with a potential outcome, a probability represents the likelihood that a future event will occur. Each probabilistic factor has two states (e.g., "Not Decreasing" and "Decreasing"). We need to estimate the probability of the factor being in one of these two states in the future (for the other state, we can simply subtract from 100). In each of the sheets in the workbook, the experts are asked to provide a probability for the state corresponding to the "good" outcome (the column for the "bad" outcome is calculated and therefore updates automatically and requires no direct input from the team members). Please see a list of supporting information that will help in general when assigning utilities to the two types of probabilistic factors: 1) external drivers, and 2) intermediate drivers and fundamental objectives.

External Drivers:
You will see that some tabs in the spreadsheet ask for just a single probability. In the case of external drivers, there are actually two probabilities representing the likelihood of being in each of the two possible states (e.g., "Rosy" and "Not So Great"; see example here). For the external drivers (budget, extreme events, etc.), we determined the criteria for the "Rosy" and "Not So Great" scenarios. The question to elicit one of the two probabilities for an external driver would be something like:

Extreme events: What is the likelihood or probability (0-100) that extreme events will be Rosy 2015-2029?

Outcomes:
You will notice that some tabs have multiple rows of probabilities to fill in. Whereas external drivers have no influencing factors, stochastic factors representing outcomes (i.e., intermediate drivers and fundamental objectives; for example an attribute of biotic integrity like change in acreage of high-quality tidal marsh) are predicted by one or more driving factors (alternative allocation, external driver, and/or intermediate driver). Please see two examples to illustrate this: marsh vegetation acreage and subtidal biotic integrity. In each case, there are driving factors that each can take two states, representing good vs. bad states. The question for each outcome requires that the team members consider the states of each of the driving factors when filling in their probabilities

The allocation (decision), budget (i.e., resource availability; external driver), extreme events (external driver) are drivers for many outcomes. When filling in probabilities, team members should refer to the external-driver scenarios, allocation options, and influence diagram for the particular subregion and ecosystem. The latter two documents can be found within the respective subregional subfolder on google drive. Referring to these documents will help you to assign probabilities.

Example, Marsh vegetation acreage for North Bay (Row 7): What is the likelihood or probability (0-100) that marsh vegetation acreage will at least remain at the current levels if the [Rosy] budget allocation strategy is chosen for the 2015-2029 time frame, the budget actually is [Bad], precipitation is [Rosy], and extreme events are [Bad] over the 2015-2029 timeframe? Square brackets here indicate that one of the two possible states is given as an example. For intermediate drivers and fundamental objectives, the questions will iterate through each combination of the states of the driving factors, corresponding to each row in the spreadsheet tab.

A challenging aspect of assigning probabilities to many of the outcomes is that team members must distinguish between budget allocation strategy (the decision, which took into account contrasting possible futures with respect to resource availability and environmental processes) and the uncertainties about what the budget and environmental drivers will actually be. It might be helpful to first think about the scenario for a given factor in row 2 (in the example), in which the choice of the allocation alternative and the actual external drivers match. Next, consider the scenario in row 10, in which the decision made is to allocate for a “bad bad” external-driver scenario, but the actual drivers turned out to be “rosy”. How would this mismatch between the chosen allocation and actual external drivers affect the outcome if at all?

The biotic integrity of each ecosystem will be elicited in a similar fashion, and illustrated here by an example for subtidal/intertidal flats in North Bay (row 7):

Subtidal/intertidal flat biotic integrity: What is the likelihood or probability (0-100) that the biotic integrity of the subtidal and intertidal marsh ecosystem complex will not decrease if shorebird abundance is [Rosy], shellfish acreage is [Bad], eelgrass acreage is [Rosy], diving duck forage availability is [Rosy], and the abundance of native fishes is [Bad].

The change-in-biotic-integrity factors are capturing the tiered structure of the fundamental objectives. Even though the integrity of each ecosystem attribute is of fundamental importance, we are simplifying the decision model by relating each of these attributes to a higher-order fundamental objective of change in biotic integrity for the entire ecosystem that integrates the various ecosystem attributes. Continuing the example above, if you believed that biotic integrity of subtidal/intertidal flat was poorly represented by diving duck foraging ability, then the likelihood of increasing biotic integrity for this scenario (Row 7) would be similar or equal to another scenario where the only difference is that diving duck forage availability is Bad (Row 9).

Appendix H Additional lessons learned from decision framing

This appendix is a companion to section 7.1, and provides additional details about lessons learned during the decision-framing step of the CADS project (see also section 3.1).

H-1.1 Project start through webinar series

It was valuable for the leadership team to spend several conference calls to develop the initial decision framing before engaging stakeholders. Without a clear starting focus, it would have been difficult to communicate with stakeholders about the aims and intended scope of the project.

Having a core team of stakeholders provide feedback on the initial decision frame and project design was an essential starting point for engaging a broader suite of stakeholders. Discussions during this early webinar helped ensure that the decision frame and planned products would meet the needs of stakeholders concerned about conservation in SF Bay. The core team could be used much more effectively, however. One call with this core group of stakeholders is not enough to get thorough feedback on the initial decision framing and project design. Additional phone calls with a core team would likely reveal gaps in resources needed to adequately engage a broader suite of stakeholders and to capture their inputs during the webinar series and workshop. With enough notice, a core team can assemble and provide many background and summary materials on existing conservation plans and planning tools. Through deeper engagement and communication with a core team early in the project, this could ensure more dedicated commitment and support throughout the project.

Assembling and organizing information on existing conservation plans was essential for ensuring that the CADS Phase 1 recommendations would be compatible with previously adopted conservation objectives and the diverse set of stakeholders working to conserve SF Bay. Without support from a core team of stakeholders, it was quite difficult for the leadership team alone to carry out this task; the leaders had underestimated the time it would take to assemble these key pieces of information. Due to lack of internal capacity, the focus was on reviewing existing conservation plans for the stated conservation objectives and proposed management actions. Missing was a review of existing and relevant decision-support tools, which would have been made possible through a deeper engagement with a core team of stakeholders. Having a summary of these decision-support tools would have been helpful to better inform the upcoming expert elicitation process.

The series of four orientation webinars with a broader suite of stakeholders was valuable for discussing the decision frame and sketching out some of the key ingredients for arriving at recommended resource allocations for each subregion. Having the leadership team respond to questions from stakeholders that arose throughout the webinar series was important to keep the process open and transparent. That said, it was a great challenge for the leaders to provide thorough responses with usually only one week between webinars on top of assembling the necessary preparatory materials and presentation for the subsequent webinar. Again, it would be helpful to have the support from a broader suite of stakeholders and a project manager that can delegate and track tasks during these hectic periods of the project. With a higher level of organization and capacity during the webinar series, the leaders working with a core team can develop a more firm structure of decision elements (e.g., objectives and action categories) and supporting materials (i.e., summaries of conservation plans and decision-support tools) to be used for arriving at draft recommendations for each subregion during the upcoming workshop.

Although not a primary focus, the webinar series was also useful for describing how structured decision making (SDM), along with its own set of jargon, would be applied as a process in reaching these recommendations. Despite an effort to downplay the importance of the process in favor of getting to useable products for decision-makers, stakeholders indicated that too much time was spent on describing the process. It is difficult to find the right balance, but one insight we had was that when describing SDM the terminology should be clearly defined and whenever possible the terms should match those that are familiar to the stakeholders. For example, SDM uses the term ‘fundamental objectives’ for the ultimate desires of stakeholders when making a decision. In this report, we use the term ‘conservation objectives’ instead, because it is more familiar to stakeholders and avoids using unfamiliar jargon. The original jargon of SDM was used during the webinar series when describing the process in an effort to stay more general, but it was confusing for the stakeholders to not use more familiar terminology within the decision context. This led to a lot of time being spent on defining and re-defining terms, time that could have been more efficiently devoted to the CADS process.

H-1.2 Stakeholder workshop

The workshop that followed the webinar series was critical to the success of CADS Phase 1. During plenary, broad agreement was reached about the overall structure of the decision to be made within each subregion. There was also general consensus about key ingredients for subregional decision tools, including conservation objectives, action categories, future scenarios for resources and external environmental drivers, and an approach to develop resource allocation options. Each subregional breakout group developed a draft decision tool (comprised of an influence diagram showing linkages between the key ingredients) that was to be completed following the workshop. Having a clear set of guidelines (Appendix D) is key to having the breakout groups provide the needed products by the end of the workshop.

Timing.-The leaders originally anticipated that the subregional decision tools would be developed and finalized through the orientation webinar series and stakeholder workshop alone. Originally, there was great concern of asking for too much time commitment from stakeholders and maintaining the CADS process as an efficient use of their time. The leadership team learned through the webinar series, however, that a number of the participants were concerned that there would not be enough time to complete these intermediate products to their satisfaction by the end of the workshop. At the workshop, then, the leadership team used a more scaled-back approach that allowed more time to develop complete drafts of the necessary ingredients, which could then be refined through further work after the workshop. Given the scope and complexity of the tasks during the workshop, however, 2.5 days felt very rushed. The 2.5-day format was originally chosen as a result of feedback from the 2011 workshop and input from stakeholders that they would be unable to commit to a week-long process, especially given the number of participants that were invited to be involved in CADS. Having 3.5 days would allow the stakeholders to complete their draft subregional decision tools with enough time to review each of them in plenary on the final morning. With only 2.5 days, the subregional teams struggled to complete their draft decision tools by the end and there was no time to discuss them in plenary and to discuss next steps. Furthermore, it is crucial to communicate clearly with stakeholders that the intended product of the workshop is a draft set of decision tools that will be refined with a core group of stakeholders following the workshop. Otherwise, there is a sense of disappointment about unfinished work.

Some stakeholders believed that it would have been better to wait until BEHGU was finalized before holding the CADS workshop. When the CADS Phase 1 project was funded, BEHGU was scheduled to be completed in mid-2014. The leadership team therefore postponed scheduling the webinar series and workshop until spring/summer 2014. At that time, however, finalization of BEHGU was delayed until July 2014. In consultation with BEHGU leadership, the CADS leadership team decided to schedule the CADS workshop in May and the preparatory/orientation webinars during April. They reasoned that by this time, the draft subregional BEHGU recommendations would be available and could be incorporated in the CADS process. As it turned out, the recommendations were drafted but not finalized before the workshop in May, but we did incorporate the draft recommendations into the CADS process as thoroughly as possible. Coordination with leaders of parallel conservation planning processes and clearly communicating with a broader suite of stakeholders about the paired timelines is important to maintain stakeholder buy-in and avoid criticisms of lack of coordination at the leadership level.

Although the plan was to complete influence diagrams and a scaled-back elicitation process during the workshop, the amount of time needed to refine the decision-question and review the SDM process consumed a significant portion of the workshop time. Some participants expressed frustration with having committed the time and not finalizing a product. Therefore, a process was developed whereby each of the subregional working groups would continue to review and refine their decision models over time. This enabled the process to better incorporate the BEHGU recommendations as they were finalized, allowed participants to incorporate recommendations from other regional planning documents, and allow for review and refinement of the subregional decision tools. Some participants who were either frustrated or had not expected to commit further time to the process decided not to continue, while others checked in at key points in the process. The continuation of the decision tool development also engaged some additional participation from individuals who were unable to attend the workshop,

Spatial scales.-Stakeholders that were more accustomed to working together and developing conservation plans for a particular subregion were relatively complimentary of the approach used during the workshop. In particular, they appreciated splitting stakeholders into subregional groups to work toward recommended subregion-specific resource allocation options. Others who were more accustomed to focusing on individual projects expressed concerns that the scope of the decision was too broad, or they at least struggled to see beyond the spatial boundaries of the locations where they worked. Some stakeholders wanted to start by applying the structured-decision-making approach to finer-scaled, project-level decision questions rather than starting with such a complex multi-scaled one. The project proposal for CADS Phase 1 was part of a larger proposal that included a second phase that focuses on developing recommendations for a particular conservation area, using San Pablo Bay National Wildlife Refuge as a case study. The leaders believed that the SF Bay-wide ecosystem and subregion-specific decision tools would inform the structure of a refuge-specific decision tool, embedding it within the broader regional-scale decision question. A challenge, then, in

CADS Phase 1 was developing a culture of subregion-scale collaboration that had not existed before the project in some of the subregions. Time must be invested in developing these collaborations, ideally in a workshop setting, before expecting progress on identifying recommendations for resource allocations that span multiple stakeholders.

Process and preparation.-It was very valuable distributing a hardcopy information packet containing information about the project, detailed progress to date, and a guide to workshop breakouts (Appendix D). Lacking, however, were additional documents describing existing decision-support tools and other conservation planning documents that would have been useful as reference particularly during breakout sessions. In particular, some stakeholders involved with the BEHGU commented that the BEHGU segment-level recommendations and future sediment and sea-level rise scenarios were not presented in a way that was useful to the participants.

Although the collaborative decision analytic (CDA) and embedded structured-decision-making (SDM) approaches (Thorne et al. 2015) were valuable for generating products needed to arrive at subregional recommended allocations, many stakeholders struggled to follow along with the process due to their lack of familiarity with it. Aside from the leaders and core team, almost none of the stakeholders had previous experience in applying CDA or SDM to addressing a conservation decision question. Even though preparatory materials were made available and presented briefly during the webinar series, it was not sufficient for ensuring everyone could follow along during the workshop. As stated above, the codified SDM terminology should be translated into a familiar language for all the participants. The difficulty, however, is that describing the SDM process in terms that newcomers can easily understand can take multiple days of focused discussion and working through examples before users gain a basic understanding of the process and can use it with simple conservation projects. Finding a common set of terminology across a broad set of stakeholders under any context presents a great challenge. Even if a majority of stakeholders follow a common set of terms, there will likely be a significant number of individuals who have differing sets of terms and/or contrasting definitions for the same set of terms. Whatever the vernacular, there must be time invested in defining and discussing terms until all participants are speaking the same language. We did find that it was effective pairing an SDM expert with a subregional coordinator that could help ensure the terminology was understood during the breakout sessions.

Roles and expertise.-There were at least two unfilled organizational roles that would have increased efficiency and quality of products from the workshop. First, in addition to having one SDM expert and one locally knowledgeable coordinator per breakout group, it would also be useful to have another SDM expert who roams between breakout groups to ensure products were being produced in a timely and consistent fashion. Although there are unique conditions in each subregion, it is important to integrate and represent them in a consistent manner and whenever possible to use the same set of measurable conservation objectives and action categories in each subregion so they can scale up across subregions. Second, some stakeholders were concerned that assumptions going into the process were not being documented adequately. By having someone explicitly assigned to note-taking in plenary and one note-taker for each breakout group, this would ensure thorough documentation of assumptions and definitions for each component of the subregional decision tools.

In addition to filling additional organizational roles, ensuring adequate representation of the relevant decision-makers and experts in each of the breakout groups is important. Although a broad range of experts were invited to participate, not all who were invited were available to attend the workshop. Some breakout groups therefore lacked representatives of particular stakeholder groups that manage significant amounts of land in their focal subregion, and other groups lacked expertise especially with subtidal and intertidal ecosystems, climate change, and sediment dynamics. Some experts at the workshop had already worked through many of the scientific questions being raised for CADS (as part of the BEHGU process), but there were other experts at the workshop who had not been involved with BEHGU and so they needed to get up to date with some of the information that had already been developed. Expertise lacking throughout was economic forecasting, which would have given the subregional breakout groups a better sense for future resource availability. A gap analysis of needs for expertise should be conducted as preparation for an SDM workshop, to ensure that all the necessary knowledge is present. That said, the SDM process itself can be used to identify the crucial uncertainties and where additional expertise is needed through sensitivity analysis.

Following the workshop.- We recognized that some references that had not been compiled in advance were needed to complete the subregional decision tools. For example, the Subtidal Goals were summarized and made available for each of the subregional groups. Providing key background information and documents is important to ensure that the subregional allocation recommendations are based on existing research and conservation planning efforts.

Although not originally planned, working with a small group of stakeholders to revise and complete the subregional decision tools over the course of several months following the workshop was essential to the success of this project. We cannot overemphasize the importance of stakeholder engagement over an extended period to ensure that the decision tool structure, composition, and associated recommendations are sufficiently vetted and usable by the stakeholders involved.

Some stakeholders called for more consistency in developing recommendations for each of the subregions. In particular, they wanted to have more discussions with the entire group of stakeholders following the workshop but before completing the decision tools on choosing key elements that could have been made more consistent among subregions (i.e., action categories and measurable attributes for the objectives and other model components). Although there was some cross-over in refining the decision tools after the workshop via the leadership team, the action categories and possibly measurable attributes could have been developed more consistently to allow for better integration among subregions. The leaders did hold two draft results webinars to which all stakeholders were invited, but by this time some of the decision tools had already become draft final and stakeholders were unable to revisit and revise them to achieve more consistency among subregions. Having additional discussions, while potentially very valuable, would have required additional time commitment from stakeholders who were already stretched thin with completing the decision tools. Planning and communicating the time commitment required to work through the steps of the project are critical to having useful recommendations at the end.

Appendix I List of files available for download

The following files are available for download at this web address: http://climate.calcommons.org/cads.

1. Project final report
2. Decision tools: Bayesian decision networks
3. Final webinar