Point Blue

Marsh-Upland Transition Zone Climate-smart Restoration Tool User Guide

For San Francisco and San Pablo bays, California, USA

September 28, 2017

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INTRODUCTION

This document is a companion to the Marsh-Upland Transition Zone Climate-smart Restoration Tool, hereafter Tool, available at www.pointblue.org/restorationtools. This document describes how to use the Tool, sets context, and provides supporting information.

Today, efforts to restore San Francisco Bay Area transition zones are growing, while the impacts of climate change and sea level rise are already being observed. By applying Climate-smart restoration principles (Gardali et al. in prep.) to transition zone restoration projects, practitioners can increase the likelihood that projects will adapt to a changing climate and continue to provide functions that support wildlife and human communities into the future (Overton 2015, Shellhammer and Barthman-Thompson 2015, Baylands Goals Science Update 2015).

What is the Transition Zone?

The estuarine-terrestrial transition zone is the area where the tidal edges of San Francisco and San Pablo bays meet with adjacent terrestrial and riverine landscapes, resulting in a mosaic of habitat types, species assemblages, and ecosystem services distinct from those of adjoining ecosystems (Baylands Goals Science Update 2015).

The Baylands Goals Science Update (2015) defines the extent of the transition zone as follows: "the transition zone extends landward (across wetlands and uplands, and along streams and rivers) to the limits of tidal effects on terrestrial and fluvial conditions. It extends bayward (across marshes and sloughs) to the limits of the effects of terrestrial runoff and other freshwater discharges on conditions of the baylands."

Historically the transition zone was hundreds to thousands of feet wide, where gently sloped topography facilitated a slow transition between estuarine and upland habitats (Collins and Grossinger 2004). Today as much as 90% of historic transition zone habitat has been lost (Shellhammer 1982), and is now replaced by steeper and narrower transitions often occurring on levee slopes (Baye 2012b). These narrower transitions don't provide the same ecosystem services as historic, gradually sloped transition zones (Fulfrost et al. 2015). As a result of these and other changes, a number of animal and plant species associated with the transition zone, including Ridgway's rail (*Rallus obsoletus*), California black rail (*Laterallus jamaicensis coturniculus*), salt marsh harvest mouse (*Reithrodontomys raviventris*), salt marsh wandering shrew (*Sorex vagrans halicoetes*), soft bird's beak (*Cordylanthus mollis ssp. mollis*), and salt marsh owl's clover (*Castilleja ambigua ssp. ambigua*), have declined in abundance and are listed for special conservation efforts (Baylands Goals Science Update 2015).

The transition zone can be categorized into subzones based on ecosystems services (Fig. 1), or based on geomorphology (e.g., alluvial fan or bluff transition zones) (Baylands Goals Science Update 2015). This Tool focuses on subzone 2, which, despite being narrower than other subzones, encompasses gradients of salinity, moisture, and nutrients that generate greater vegetation diversity and heterogeneity than other subzones (Fulfrost et al. 2015). In addition to a diverse flora, subzone 2 provides foraging habitat for many animals such as coyotes, birds of prey, reptiles, small mammals, amphibians, and migratory and songbirds (Fulfrost et al. 2015), and nesting habitat for resident birds and macro invertebrates, such as relatively abundant and understudied insects and spiders (Goals Project 2000).

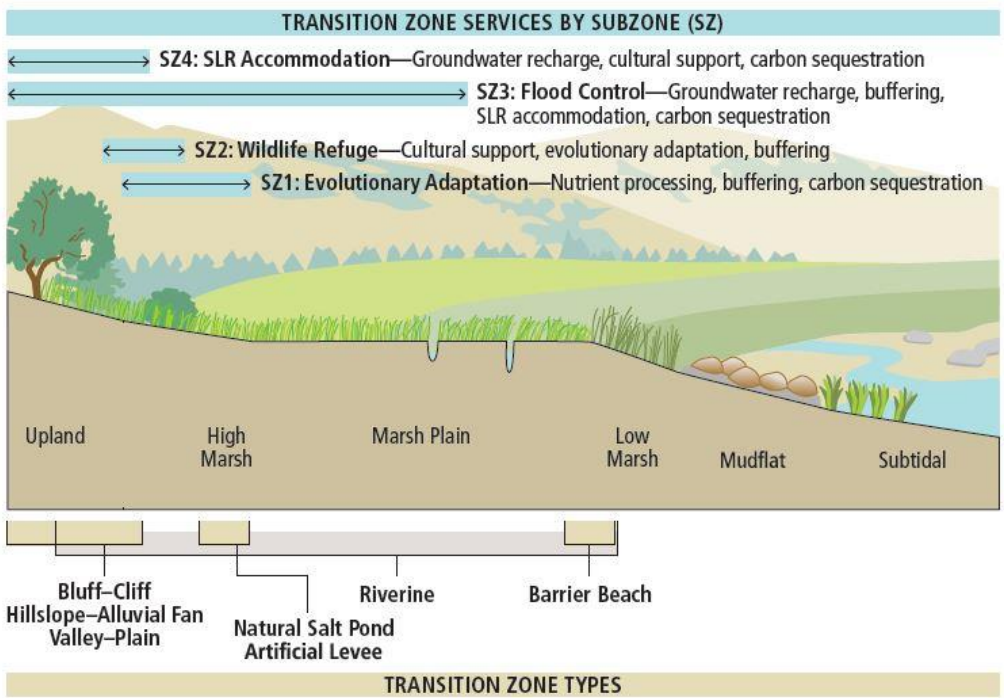

Figure 1. Spatial relationships among transition zone types and subzones. Subzone 3 and 4 extend landward of the upland extent shown in this figure. The riverine type extends bayward to the limits of the effects of freshwater discharge on intertidal vegetation. The primary services of each subzone are shown in bold. Services common to all transition zone types, such as wildlife movement and landscape complexity are not shown (Baylands Goals Science Update 2015).

This Tool was developed to address climate change impacts associated with subzone 2 (Baylands Goals Science Update 2015), as well as climate change impacts to plant survival and natural recruitment. The Tool specifically addresses these services provided by transition zones:

- Provide high water escape or refugia habitat for marsh animals, including endangered species like the Ridgway's rail, and salt marsh harvest mouse
- Provide foraging and nesting habitat, and movement corridors for terrestrial wildlife
- Prevent erosion from wind and boat waves
- Prevent colonization and proliferation of invasive species (biological buffering)

Applying the Tool for Climate-smart Restoration

Climate-smart restoration encompasses every step of restoration; this Tool, however, was specifically designed to evaluate plant species ability to survive, recruit and provide desired ecosystem services in a changing climate. Many other factors should be considered when designing and implementing a transition zone restoration project, such as site hydrology, soil type, seed source, land use, existing species assemblages, and more. This Tool does not attempt to provide guidance across all important areas of consideration.

The Tool is based on an annotated list of native plant species documented in San Francisco and San Pablo bay transition zones. See Table 2 in 'Plant List Sources' for information about the selection criteria used to generate this list, and 'Where to Use the Tool' for geographies appropriate for applying the Tool. Selected plant species fall into three groups: forbs, graminoids, and shrubs. Although trees occur in subzone 2 of some transition zones (i.e. China Camp State Park), trees were excluded from the Tool because they provide roosting and nesting habitat for raptors that could depredate wildlife, and reduce the value of transition zone habitat as high tide refugia for species such as the Ridgway's rail and salt marsh harvest mouse (U.S. Fish and Wildlife Service 2013).

Our approach was to evaluate the projected impacts of climate change on transition zones, and identify key plant traits that enable native transition zone plants to cope with these impacts while continuing to provide desired ecosystem services. Projected changes in temperature, precipitation, and sea level will directly impact Bay Area transition zones (Veloz 2013, Baylands Goals Science Update 2015), and the wildlife that rely on this unique type of habitat (U.S. Fish and Wildlife Service 2013). Projected climate change impacts include but are not limited to (Baylands Goals Science Update 2015):

- more frequent and extreme displacement of wildlife due to increased frequency and severity of storms and flooding
- increased summer air temperatures and frequency and severity of drought
- increased variability of timing and quantity of precipitation
- increased salinity, especially at upland edges due to sea level rise and drought
- decreased salinity, especially in riverine areas prone to flooding
- increased erosion from storm-generated wind waves
- landward migration of tidal marsh, and compression of transition zones where steep topography or land use limits upslope accommodation space (e.g., levees, bluffs)

Climate change and the compounding impacts of invasive species may make survival and recruitment more challenging for many transition zone plant species, especially the increased variability of precipitation and associated effects of drought, as well as salinity increases (from drought and sea level rise) and decreases (from precipitation and freshwater flooding). For this reason, we identified two traits (Drought Tolerance and Salt Tolerance) that we hypothesize will increase plant survival under future conditions. We identified four dispersal traits that we hypothesize will improve the probability of re-colonization and recruitment of native vegetation following a disturbance event (Rhizomatous, Tidally, Wind and Wildlife Dispersed).

Projected changes in climate will also impact transition zone wildlife (U.S. Fish and Wildlife Service 2013). Two traits were selected to support wildlife food webs (Insectary Plant, Wildlife Dispersed) and one trait was selected to provide refuge during flooding (Tall Dense Vegetation for Refugia). See Table 1 for a full list of plant traits and the rationale for their inclusion.

Table 1. Plant traits included in the tool and their rationale for inclusion. Plant survival traits are shown in blue, disturbance resilience traits are shown in orange, and wildlife support traits are shown in green.

Trait	Rationale
Drought tolerant	increases probability of survival in a warmer climate with more variable precipitation
Salt tolerant	increases probability of survival in hypersaline condition caused by drought and coastal flooding
Rhizomatous	prevents erosion and biological invasion, and increases likelihood of post-disturbance recruitment of native vegetation
Wind dispersed	increases likelihood of post-disturbance recruitment of native vegetation, which prevents biological invasion
Tidally dispersed	increases likelihood of post-disturbance recruitment of native vegetation, which prevents biological invasion
Wildlife dispersed	supports food webs with fruit/seed sources for wildlife and increases likelihood of post-disturbance recruitment of native vegetation, which prevents biological invasion
Tall dense vegetation for refugia	provides refugia during marsh flooding caused by sea-level rise and more frequent and severe storms
Insectary plant	supports food webs with flower and invertebrate resources as well as provides pollination services

How to Use the Tool

The Tool is designed to help restoration practitioners plan for climate change by identifying plant species that have traits that will increase the likelihood that they will survive, recruit, and continue to provide important ecosystem services under projected conditions.

To use the Tool, we recommend that practitioners first consult an expert to create a site-appropriate planting list for their project based on native plant assemblages of nearby reference sites. The list can then be evaluated with this Tool to ensure that it includes species that have traits that enable them to persist, recruit, and function.

The goal of users should be to ensure that all traits are represented in a planting list, and ideally, that each trait is represented by multiple plant species, thereby providing ecological redundancy, which increases ecosystem resilience (Shigeo and Loreau 1999). If any traits are not well-represented in the species selected, then practitioners can begin a discussion with local experts about which species may need to be added to the restoration design in anticipation of climate change. Finally, by summarizing how the Tool was used to inform and refine the planting list, restoration practitioners can demonstrate the process by which they ensured their planting list is designed to accommodate climate change.

If practitioners wish to evaluate species not already incorporated in the Tool, they can easily add species by following directions in the Tool. While the Tool can be used to identify species with beneficial traits (e.g. salt tolerant), always consult an expert to determine if species are well-suited to a project site and goals before inclusion in a restoration design.

Where to Use the Tool

The Tool is suited for transition zone habitats of San Francisco and San Pablo bays, California, referred to collectively as Bay Area transition zones. Many transition zone restoration projects occur on levee slopes, and may include uplands outside of the transition zone as defined above. While we recognize the importance of conserving and restoring adjacent uplands, planting recommendations for areas outside (or upstream of) transition zones is outside the scope of this Tool. For climate-smart planting recommendations for riparian areas see the Riparian Restoration Design Database tool at at www.pointblue.org/restorationtools. For a description of plant communities found adjacent to Bay Area tidal marshes see Chapter 1., Section e., “Plant Communities Ecotonal to the Baylands,” of the Goals Project (2000).

PLANT TRAIT DEFINITIONS

Plant Survival Traits

The following traits were selected to increase plant survival in a changing climate. Climate projections for Bay Area transition zones include increased temperatures and variability of precipitation, and associated increased drought and salinity variability.

Drought Tolerant

Rationale: Climate models project that future conditions in the Bay Area will be warmer, exacerbating the vulnerability to impacts from drought (Cayan et al. 2012). Warming increases the probability that years with low precipitation will coincide with high temperatures, increasing the frequency, intensity, and severity of drought events (Diffenbaugh et al. 2015). Considering these projections, restoration projects that include drought tolerant plants may have better survival during periods of high moisture deficit.

Definition: Based on USDA's Conservation Plant Characteristics Data Definitions, drought tolerant species were defined as those typically found in coarse, well-drained soils with low soil-moisture relative to species of the same growth form that occur in the same geographic area. Drought tolerance of each species was based on USDA Conservation Plant Characteristics Data and Wetland Indicator Status when USDA data were not available. A comparison of USDA Conservation Plant Characteristics Data and Wetland Indicator Status found parallels used to classify plant species as:

High – Plant reported to have high drought tolerance or Wetland Indicator Status of Obligate Upland

Medium – Plant reported to have medium drought tolerance or Wetland Indicator Statuses of Facultative or Facultative Upland

Low – Plant reported to have low drought tolerance or Wetland Indicator Status of Facultative Wetland

None – Plant reported to have no drought tolerance or Wetland Indicator Status of Obligate Wetland

Salt Tolerant

Rationale: Climate models for the San Francisco Bay Area predict an increase in both the rate of sea level rise (National Research Council 2012, Cayan et al. 2016) and the frequency of extreme tidal and coastal storm events (Cayan et al. 2008). This could lead to longer and more frequent periods of saline inundation for plants in the transition zone. By incorporating plant species that tolerate saline conditions, practitioners can help ensure that species selected for restoration are prepared for the impacts of sea level rise and storms. For more information on how combinations of sea level rise and coastal storm scenarios might affect San Francisco Bay, visit www.ourcoastourfuture.org.

Definition: Based on USDA's Conservation Plant Characteristics Data Definitions, tolerance to a soil salinity level is defined as only a slight reduction (not greater than 10%) in plant growth. Published information from Calflora and USDA Conservation Plant Characteristics Data were used to classify plant species' salt tolerance as:

High – Tolerant to a soil with an electrical conductivity greater than 8.0 dS/m

Medium – Tolerant to a soil with an electrical conductivity of 4.1-8.0 dS/m

Low – Tolerant to a soil with an electrical conductivity of 2.1-4.0 dS/m

None – Tolerant to a soil with an electrical conductivity of 0-2 dS/m;

Disturbance Resilience Traits

The following traits were selected to increase the likelihood that native vegetation can recolonize areas disturbed by flooding, salinity changes, and erosion, which are projected to increase in a changing climate. Ecological resilience to disturbance increases with diversity (Holling 1973, Gunderson 2000, Baylands Goals Science Update 2015), thus by incorporating plants with a diversity of dispersal mechanisms, restoration projects may be more resilient. To maximize post-disturbance recruitment of native plants, practitioners should include plants with a range of dispersal mechanisms, and consider growth and seed production rates, which may also increase native plant recruitment and prevent invasive species colonization. Plants that spread by rhizome may also aid in rapid post-disturbance regeneration, and can reduce erosion and colonization of invasive species (Baye 2008, Baylands Goals Science Update 2015).

Rhizomatous

Rationale: Plants with rhizomes or underground stems have the ability to reproduce vegetatively (without flowering or producing seeds), and can spread from a single individual to colonize a larger area. Many newly constructed levees, and other transition zone restoration sites, can become colonized by invasive plants and weeds that out-compete native species. Incorporating rhizomatous plants into a restoration design helps ensure that the restoration site will be quickly colonized by native plants, and may help reduce openings where invasive plants can establish (Baye 2008). Transition zones with dense native vegetation can buffer adjacent intertidal habitats from invasive terrestrial plants (Baye 2008, Wasson and Woolfolk 2011, Baylands Goals Science Update 2015), and help prevent erosion by dissipating wind and boat waves during hide tides and flooding (Garbisch and Garbisch 1994, Baye 2008, BCDC 2011).

Definition: Plants in this category have rhizomes, and reproduce vegetatively. Published information in Jepson eFlora and expert opinion were used to classify plant species as:

Yes – Plant spreads and reproduces via rhizomes, or underground stems
No – Plant does not have rhizomes

Tidally Dispersed

Rationale: In tidal wetlands, tidal seed dispersal has been shown to result in higher density, diversity and overall quantity of seeds compared to wind and wildlife dispersal (Chang 2005, Neff 2005). Therefore, tidally dispersed plants in San Francisco Bay (like salt marsh gumplant, *Grindelia stricta var. augustifolia*) may be more likely than plants with other primary dispersal mechanisms to recruit naturally in transition zones. Intentionally planting tidally dispersed species could expedite their establishment and help future recruitment. Furthermore, incorporating tidally dispersed plants in areas of increased tidal flow (e.g., slough mouth), or adjacent to unrestored areas or sites where future disturbance events are likely, could help desired species spread with less human investment.

Definition: Species in this category have seeds or propagules that are dispersed tidally. Published information from Dispersal Diaspore Database, and peer-reviewed literature were used to classify plant species as:

Yes – Plant propagules or seed can be dispersed by water
No – Plant propagules or seed do not disperse by water
? – Information unavailable, inconclusive, or of inadequate quality

Wind Dispersed

Rationale: Transition zones are often windy because of their proximity to open waters where air movement is unobstructed and thermal gradients are common. Seeds that are small and light enough to be carried on the wind can travel great distances depending on air currents and weather patterns. Planting species that disperse seeds by wind may help colonization after disturbance, and may also seed down-wind areas. Like tidally dispersed species, incorporating wind dispersed species adjacent to unrestored areas or sites where future disturbance may help native vegetation spread with less human investment.

Definition: Species in this category have seeds that are dispersed by wind and air movements. Published information from Dispersal Diaspore Database, and peer-reviewed literature were used to classify plant species as:

Yes – Plant seed can be wind dispersed
No – Plant seed is not wind dispersed
? – Information unavailable, inconclusive, or of inadequate quality

Wildlife Support Traits

The following traits were selected to 1) support basic food webs and facilitate pollination of native vegetation, which may also assist recruitment and resilience to disturbance, and 2) support wildlife by providing escape habitat, or so-called refugia, during flooding and high water events, which are projected to increase in the Bay Area.

Wildlife Dispersed

Rationale: Transition zones are diverse habitats and support many fauna that migrate, feed, or take refuge in this unique habitat (SFEI 2007). Plants that are dispersed by wildlife often provide food resources to animals (such as the fruit encapsulating a seed), in addition to dispersing and recruiting successfully when wildlife are present. Transition zones provide plant and animal movement corridors (Baylands Goals Science Update 2015), and incorporating plants dispersed by wildlife takes advantage of this service to increase colonization potential.

Definition: Species in this category have seeds that can be dispersed by wildlife. Published information from Dispersal Diaspore Database, and peer-reviewed literature were used to classify plant species as:

Yes – Plant seeds can be wildlife dispersed
No – Plant seeds are not wildlife dispersed
? – Information unavailable, inconclusive, or of inadequate quality

Tall Dense Vegetation for Refugia

Rationale: Many animals that inhabit the tidal marsh take refuge in transition zones during high tides, storm surges, and other flood events, including species of concern for management like the California black rail, and salt marsh wandering shrew (Baylands Goals Science Update 2015). The salt marsh harvest mouse and Ridgway's rail are federally endangered species that live in tidal marshes in San Francisco and San Pablo bays (U.S. Fish and Wildlife Service 2013). Both species rely on dense, perennial marsh vegetation for nesting and foraging, and taller, year-round vegetation within the marsh and transition zone to escape predators during high tides and flooding (Smith 2012, Overton 2015, Shellhammer and Barthman-Thompson 2015). In a changing climate, sea level rise and an increase in the frequency and severity of storms puts additional pressure on these endangered species, and many others that rely on transitional vegetation for refugia (Nur and Herbold 2015).

A plant's ability to provide high water refugia to wildlife depends on its height, stem density, and the time of year that plant structures are present (Baylands Goals Science Update 2015). Plants with dense year-round structure above the level of tidal inundation can provide refuge to marsh animals during extreme tides, storm surges and flooding (Baye 2008, Baylands Goals Science Update 20152015). Plant species known to provide refugia include but are not limited to evergreen species like pickleweed (*Salicornia pacifica*), as well as species like alkali bulrush (*Bolboschoenus maritimus*) and marsh gumplant that senesce annually but can retain dense above-ground structures through the winter (Baye 2008).

Mature Height: While large vegetation may provide better cover for some animals, woody plants with mature heights over 2 m can also be used as predator perches (U.S. Fish and Wildlife Service 2013), which degrades the value of refugia habitat. In the Tool, mature height of each species is reported in meters and is estimated to the nearest 0.1 meters. Practitioners should be advised that planting woody plants with mature heights 2 m or higher can degrade the value of refugia habitat by creating habitat for predators, such as roosts for raptors.

Definition: Multi-stem plants with mature heights between 0.25 and 2 m that maintain dense structure year-round. Published information in Jepson eFlora and expert opinion were used to classify plant species as:

Yes – Species has dense structure year-round from 0.25 to 2 m in height
No – Species lacks one or more of the traits needed to provide year-round refugia
? – Information unavailable, inconclusive, or of inadequate quality

Insectary Plant

Rationale: Bay Area transition zones have high biodiversity, including a relatively high abundance of macroinvertebrates, like insects and spiders (Baylands Goals Science Update 2015). Insects provide pollination to transition zone and tidal marsh plants (Baylands Goals Science Update 2015), and are also widely expected to play important roles as pollinators, herbivores, scavengers, predators, and prey in life cycles of other species (Goals Project 2000). Incorporating plant species that support insects may provide many services and support overall biodiversity and resilience.

Definition: Plants in this category are known to play a role in an insect's lifecycle, and/or benefit insects by providing habitat. Published information on Calflora was used to classify plant species as:

Yes – Plants in this category are known to play a role in an insect's lifecycle, and/or benefit insects by providing habitat

No – Plant is not known to be used by or beneficial to insects

? – Information unavailable, inconclusive, or of inadequate quality

PLANT LIST SOURCES

Table 2. Sources documenting native plants present in Bay Area transition zones used to identify the species included in the Tool, and the parameters used to determine inclusion/exclusion of species for each source.

Sources	Inclusion Parameters
Baylands Ecosystem Species and Community Profiles: Life histories and environmental requirements of key plants, fish and wildlife (Goals Project 2000).	Plants included in the Tool are documented in 'high marsh', and 'high brackish marsh' (included in the transition zone, as defined above) in chapter 1) e. "Tidal Marsh Plants of the San Francisco Estuary" by Peter R. Baye, Phyllis M. Faber, and Brenda Grewell.
Vegetation management in terrestrial edges of tidal marshes, western San Francisco Estuary, California: Integrated vegetation management strategies and practical guidelines for local stewardship programs (Baye 2008).	Plants included in the Tool are noted in chapter 3.4 "Historic and modern native vegetation of San Francisco Estuary tidal marsh edges: models and objectives for management."
Tidal Marsh Vegetation of China Camp, San Pablo Bay, California (Baye 2012a).	Plants included in the Tool are those noted as occurring in high marsh or above in "Appendix A: Tidal Marsh Vegetation of China Camp, San Pablo Bay, California."

CITATIONS

Baye, P.R. 2008. Vegetation management in terrestrial edges of tidal marshes, western San Francisco Estuary, California: Integrated vegetation management strategies and practical guidelines for local stewardship programs. Mill Valley, CA: Marin Audubon Society.

Baye, P.R. 2012a. Tidal marsh vegetation of China Camp, San Pablo Bay, California. San Francisco Estuary and Watershed Science. 10(2). jmie_sfews_11176. Retrieved from: https://escholarship.org/uc/item/9r9527d7.

Baye, P.R. 2012b. Terrestrial-estuarine transition zone typology: diagrams/cartoons and captions for SF Estuary supratidal geomorphic contact (landform) and vegetation types, structure, processes. Memorandum to Donna Ball and Josh Collins and Bay Area Habitat Goals Update t-zone workgroup cc: workgroup participants, December 4, 2012.

BCDC. 2011. Living with a rising bay: Vulnerability and adaptation in San Francisco Bay and on its shoreline. San Francisco Bay Conservation and Development Commission, final report, San Francisco CA. http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf. (Accessed 03/24/2017).

Cayan, D., P. Bromirski, K. Hayhoe, M. Tyree, M. Dettinger, and R. Flick. 2008. Climate change projections of sea level extremes along the California coast. Climatic Change 87:57–73.

Cayan, D., J. Kalansky, S. Iacobellis, and D. Peirce. 2016. Creating probabilistic sea level rise projections to support the 4th California climate Assessment. California Energy Commission. Docket number: 16-IEPR-04.

Cayan, D., M. Tyree, and S. Iacobellis. 2012. Climate Change Scenarios for the San Francisco Region. California Energy Commission. Publication number: CEC-500-2012-042.

Collins, J.N. and R.M. Grossinger. 2004. Synthesis of scientific knowledge concerning estuarine landscapes and related habitats of the South Bay Ecosystem. Technical Report of the South Bay Salt Pond Restoration Project. Oakland, CA: San Francisco Estuary Institute.

Chang, E.R., E.L. Zozaya, D.P.J. Kuijper, and J.P. Bakker. 2005. Seed dispersal by small herbivores and tidal water: are they important filters in the assembly of salt-marsh communities? Functional Ecology 19:665–673. doi:10.1111/j.1365-2435.2005.01011.x.

Diffenbaugh, N. S., D. L. Swain, and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences 112:3931–3936.

Folke, C., S. Carpenter, B. Walker, M. Scheffer, T. Elmqvist, L. Gunderson, and C.S. Holling. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. Annual Review of Ecology and Systematics 35:557–581.

Fulfrost, B., M. Marriott, C. Sloop, D. Thomsom, and L. Valoppi. 2015. The Importance of SZ2 in Marsh-Upland Transitions. Appendix 4.3 of Science Foundation Chapter 4 of The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update. 2015. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

Garbisch, E.W. and J.L. Garbisch. 1994. Control of upland bank erosion through tidal marsh construction on restored shores: application in the Maryland portion of Chesapeake Bay. Environmental Management 18(5):677-691.

Gardali, T., R. DiGaudio, N.E. Seavy, and L. Comrack. 2012. A climate change vulnerability assessment of California's at-risk birds. PLoS ONE 7: e29507.

Goals Project. 2000. Baylands Ecosystem Species and Community Profiles: Life histories and Environmental Requirements of Key Plants, Fish and Wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. P.R. Olofson, editor. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Goals Project. 2015. The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

Gunderson, L.H. 2000. Ecological resilience in theory and practice. Annual Review of Ecology and Systematics 31:425-439.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1–23.

Memmott, J., P.G. Craze, N.M. Waser, and M.V. Price. 2007. Global warming and the disruption of plant-pollinator interactions. Ecology Letters 10:710-717.

National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Washington, DC: The National Academies Press. doi:https://doi.org/10.17226/13389.

Neff, K.P. and A.H. Baldwin. 2005. Seed dispersal into wetlands: Techniques and results for a restored tidal freshwater marsh. Wetlands 25: 392. doi:10.1672/14.

Nur, N., and B. Herbold. 2015. Science Foundation Chapter 5: Risks from Future Change for Wildlife in Goals Project of The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update. 2015. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

Overton, C.T., J.Y. Takekawa, M.L. Casazza, T.D. Bui, M. Holyoak, and D.R. Strong. 2015. Sea level rise and refuge habitats for tidal marsh species: can artificial islands save the California Ridgway's rail? Ecological Engineering 74:337-344. doi:10.1016/j.ecoleng.2014.10.016.

SFEI. 2007. Ecological connections between baylands and uplands: examples from Marin County. A report to the Marin Audubon Society, Marin Conservation League, Marin Baylands Advocates, Sierra Club. San Francisco Estuary Institute, Oakland CA.

Shellhammer, H. 1982. Management problems associated with the recovery plan for the salt marsh harvest mouse and California clapper rail. The Wildlife Society Western Section. California-Nevada Wildlife Transactions. Pp: 61-63.

Shellhammer, H., and L. Barthman-Thompson. 2015. Case Study: Salt Marsh Harvest Mouse (Reithrodontomys raviventris) *in* The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015 prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. California State Coastal Conservancy, Oakland, CA.

Shigeo, Y. and M. Loreau. 1999. Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. Proceedings of the National Academy of Sciences 96(4):1463-1468. doi:10.1073/pnas.96.4.1463.

Smith, K.R. 2012. Refuge use and movement of the Salt Marsh Harvest Mouse (Reithrodontomys raviventris) in response to environmental heterogeneity. Master’s Thesis, New Mexico State University. 43 pp.

Stralberg, D., D. Jongsomjit, C.A. Howell, M.A. Snyder, J.D. Alexander, J.A. Wiens, and T. Root. 2009. Re-shuffling of species with climate disruption: A no-analog future for California birds? PLoS ONE 4(9): e6825. doi:10.1371/journal.pone.0006825.

U.S. Fish and Wildlife Service. 2013. Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California. Sacramento, California. xviii + 605 pp.

Veloz, S., N. Nur, L. Salas, D. Jongsomjit, J. Wood, D. Stralberg, and G. Ballard. 2013. Modeling climate change impacts on tidal marsh birds: Restoration and conservation planning in the face of uncertainty. Ecosphere 4(4):1-25.

Wasson, K. and A. Woolfolk. 2011. Salt marsh-upland ecotones in Central California: vulnerability to invasions and anthropogenic stressors. Wetlands 31:389-402.