THE Baylands AND Climate Change

WHAT WE CAN DO

BAYLANDS ECOSYSTEM HABITAT GOALS
SCIENCE UPDATE 2015

NEW OPPORTUNITIES

How we can achieve healthy, resilient baylands

Climate change threatens the baylands and their wildlife. It increases the magnitude and complexity of the challenges to achieving a sustainable baylands ecosystem, with urbanization, pollution, and invasive species continuing to pose significant obstacles as well. A corresponding increase in innovation, partnerships among stakeholders, and monetary investment is required to achieve ecological health in the baylands and to maintain the ecosystem services they provide to human communities.

INTRODUCTION

As human communities are threatened by climate change, so are the baylands and their wildlife. In the absence of mitigating human action, rising bay waters, reduced sediment supplies, warmer temperatures, lower freshwater inputs, more intense storms, and other changes are likely to cause significant loss of the baylands and their wildlife. If swift and sustained action is taken to achieve the project goals, as recommended here, then healthy baylands can persist into the future while protecting human communities from floods, improving water quality, and providing the recreational opportunities and wildlife habitat that are highly valued attributes of the Bay Area. Healthy and resilient baylands will help sustain healthy and resilient Bay Area communities.

A Snowy egret forages in the baylands.

Restoration practitioners strengthen the resilience of the baylands and their wildlife by restoring, enhancing, or emulating natural, dynamic physical and biological processes. Such actions rely on monitoring the baylands, taking innovative approaches, and applying a knowledge of past practices—and on these becoming a part of accepted restoration procedures and policies. To be successful, these actions also require more resources, closer collaboration among stakeholders, and quicker actions than before.

The recommended actions in this chapter update and replace those from the 1999 Baylands Goals Report. The actions are designed to preserve, protect, restore, enhance, and promote the resilience of baylands ecosystems to achieve the following vision for the next 100 years:

> *The San Francisco Estuary baylands will sustainably support robust populations of diverse native plant and animal species, while providing essential ecosystem services to human communities.*

The recommendations below lead off with overarching recommendation highlights, followed by 10 regional strategies and associated recommended actions that apply to most or all of the subregions and their segments. More detailed information for the subregions and segments follows. The recommendation highlights are the primary cross-cutting ideas that emerged from the scientific synthesis. The regional strategies elaborate on these ideas in more detail and include other recommended actions. The segment write-ups provide important contextual information about particular stretches of the baylands and indicate the most important recommended actions to take in each area.

HIGHLIGHTS

The following five highlights are the most critical overarching ideas from the recommendations. They will foster resilience to climate change so that the baylands can function as a healthy ecosystem and support native wildlife and human communities. The first two highlights directly increase baylands resilience, while the latter three improve the efficacy of resource stewardship and management.

1. Restore estuary–watershed connections that nourish the baylands with sediment and freshwater.

Finding

Sediment and freshwater are essential resources for restoring and maintaining the baylands. The rerouting of creeks, raising of levees, and building of infrastructure have removed the physical connections that deliver these resources to the baylands from their watersheds. Sediments allow baylands elevations to keep pace with sea-level rise, and freshwater is critical for moving watershed sediments directly into marshes. Freshwater also creates salinity gradients that increase biodiversity, help wildlife survive dry years, and support brackish marshes that rapidly accumulate peat, helping marshes maintain their elevation as sea levels rise and sequester carbon from the atmosphere. Historically the form of these watershed connections differed from creek to creek. Some forms of these freshwater connections can generate complex habitat mosaics of wetland types that further increase biodiversity and transition zone services. Protecting diverse watershed connection types where they exist and restoring the diversity of such connections as appropriate for local conditions and processes is important for fostering complexity (see highlight 2 below).

Watershed connections will become increasingly important to baylands sustainability.

Recommended Actions

- Restore and protect diverse types of sediment and freshwater connections as appropriate for local conditions and processes. In some cases, a connection could be restored as a natural landscape feature, such as a creek entering a marsh through a slough. In others, more artificial means may be needed to move sediment and water, such as dredging sediment from a flood channel and placing it on or near the baylands.
- Reconnect streams, and the sediment loads they carry, to the baylands. Determine how other freshwater sources, like treated wastewater effluent and stormwater, may be safely reconnected to the baylands through carefully monitored pilot projects.
- Use suitable dredged or excavated sediments (that have contaminant concentrations within acceptable limits) to the greatest extent possible within the baylands.

2. Design complexity and connectivity into the baylands landscape at various spatial scales.

Finding

A complex, connected landscape facilitates short-term population persistence and long-term species survival by enabling wildlife to adapt to a changing environment. Landscape complexity and connectivity are key to providing access to a variety of habitats that allow some portion of wildlife populations to survive hot years, dry years, extreme flooding, and other variability that is expected to increase. In addition, complex and connected landscapes promote the genetic and phenotypic diversity that is critical for wildlife to evolve in keeping with rapid environmental change. Finally, complex channel networks draining marsh plains allow natural water circulation that protects water quality.

Recommended Actions

- Restore and protect complex, connected landscapes that include topographic and salinity gradients; diverse habitat types; habitat mosaics, such as those found at the base of alluvial fans or in mature tidal marshes; variation within habitats, such as a complex of managed ponds with diverse salinities and depths; multiple habitat combinations (for example, a variety of transition zone types bordering tidal marsh); natural transitions between the habitats; and connections, like transition zone corridors or appropriately managed agricultural or parklands adjacent to baylands, that allow wildlife to pass from one area to another.
- Create connected gradients around the perimeter of the estuary. For example, connect marshes along the shoreline from salt marshes in the South Bay to brackish marshes in Suisun. At a smaller scale, protect and restore the watershed connections to the baylands. For example, maintain riparian corridors on creeks and broad transition zones between marshes and adjacent terrestrial habitats.
- Design baylands landscapes to be heterogeneous and connected at multiple spatial scales and across projects, so that no one area or project must provide all options, yet the full portfolio of complexity is represented across the region. Use local natural processes and historical and projected habitat configurations to design and create large-scale, self-maintaining, connected landscapes that support diverse native species.

3. Increase coordination among baylands stakeholder organizations to promote the successful implementation of the recommendations in this report.

Finding

Accelerating climate change drives a need for the immediate and efficient implementation of these recommendations before change becomes too rapid. The longer it takes to restore the baylands and undertake the other actions described here, the less likely it is that the ecological health of the baylands will be achieved and maintained. Environmental policies, regulations, and interjurisdictional relationships will need to evolve in keeping with new scientific information to enable the innovation and adaptive management necessary to implement the recommendations of this report successfully.

Recommended Actions

- Coordinate an adaptive management program that is based on testing hypotheses and learning from previous actions. It should (1) monitor the baylands landscape and wildlife to track ambient change and the effects of implemented actions, (2)

New scientific information drives innovation.

develop targeted applied studies, including modeling, to answer management questions and develop new approaches to restoration, and (3) develop projects to test hypotheses and new approaches and technologies.

- Centralize data access, statistical analysis, and interpretation through a consolidated effort managed by all key stakeholders that is supported by a long-term commitment to achieve regional goals with consistent funding. Apply local models like the Regional Monitoring Program for Water Quality, the Long-Term Management Strategy for Dredged Material, and the South Bay Salt Ponds Adaptive Management Program when designing the interjurisdictional partnerships.
- Facilitate and support dialogue between environmental scientists, managers, and regulators to promote the rapid diffusion of new information that allows policy to evolve in keeping with science. Create and support advisory forums to facilitate the incorporation of current science and the implementation of these recommendations into project design and management. Bring scientists together to build a better understanding of watershed processes, stream sediment dynamics, and the relationship of these factors to the accretion of sediment in the baylands.
- Coordinate more closely with the organizations that are stakeholders of delta environmental health to achieve better outcomes across the single estuary comprising the bay and delta.
- Incorporate the Science Update recommendations where appropriate in local and regional plans and resilience strategies.

Informed dialogue will improve restoration plans.

4. Create plans that factor in ecological outcomes after extreme events and other disasters.

Finding

Catastrophes in the Bay Area that are caused by extreme weather events and earthquakes are predictable in type and location but not in timing. Floods, drought, heat waves, and other environmental extremes are a significant risk to the ecological health of the baylands, and human responses to these events could impose an even greater risk over time. Planning ahead for such catastrophes can enable the development of nature-based flood-protection and other landscape designs that protect human communities while also protecting and even enhancing baylands ecosystems. Without such plans, engineered solutions may be implemented after a disaster that do not optimize the ecosystem services and ecological functions of the baylands, since these solutions are under the purview of agencies that often lack the requisite ecological mission or expertise. For example, after a flood some areas of shoreline might end up with hardened seawalls next to deep water even though a design with intertidal wetlands and subtidal habitats might offer a more optimal and durable solution for adjacent human communities.

Recommended Actions

- Integrate implementation of the actions recommended here as appropriate into response plans for catastrophes that are likely to affect the ecological functioning of the baylands, either through the catastrophe itself or the response to the catastrophe (such as building sea walls or raising levees). Opportunities for this may include updates to general plans and capital-improvement programs for cities, counties, and flood-control districts.
- In these plans, detail approaches that rely on natural processes to protect and restore ecosystem services and ecological functions. Such approaches—for

example, restoring physical processes that allow marshes to persist over time and protect the developed shoreline from erosion—will also create resilience to future events.

- Establish and cultivate relationships among the agencies entrusted with stewardship of the baylands and those that implement infrastructure changes after disasters, such as cities, counties, and flood-control districts.

5. Engage the citizenry in the baylands.

Finding

Successful implementation of the recommendations in this report is unlikely without a long-term increase in funding, education, and advocacy for the baylands. A strategy to develop the necessary level of resources must include efforts to inform and empower the local citizenry, elected officials, policy makers, and funding organizations to make decisions that promote healthy, resilient baylands. Directly engaging local residents in the baylands through recreation, volunteerism, and other field activities is another way to promote advocacy.

Recommended Actions

- Conduct outreach to voters and policy makers by framing messages about the baylands in terms the public can connect with (clean water, flood protection, recreational opportunities, water sustainability, climate change resiliency, wildlife) and providing clear and concise actions they can take.
- Partner more closely with educational organizations to transfer knowledge about baylands ecosystem services, threats to those services, the history of environmental change in the baylands, stories about local innovation and success in restoring ecological health, and interesting features of the baylands landscape and wildlife. Target audiences are registered voters in Bay Area counties, teachers in the K–12 and university-level educational system, and people who live, work, or own businesses on or near the baylands.
- Build direct engagement of the citizenry into implementation planning through appropriate recreational access to the baylands, citizen science contributions to monitoring (including crowdsourcing), volunteer labor for restoration projects, adventure learning, regional science competitions based on the challenges facing the baylands, and other such activities.

Stakeholder of the future baylands

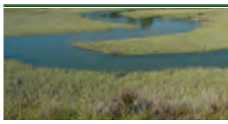
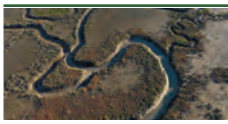
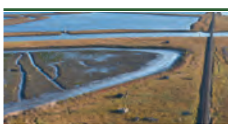
Figure 24 Artist's rendering of an envisioned future baylands depicting implementation of the regional strategies to promote resilience in the baylands landscape, its habitats, and wildlife. Here a local creek has been reconnected to the baylands, *delivering sediment and fresh-water* directly into the marsh, which helps the marsh rise in elevation as sea level rises. This restored connection also creates a *gradient of fresh to brackish to salt marsh*, providing different habitats for wildlife. The salt marsh has a *robust, complex channel system*, pannes, and an undeveloped transition zone to the upland. *Protected and enhanced transition zone* supports native plants and animals, and provides a place for the *marsh to migrate landward* as sea level rises. The continuous transition zone

around the baylands and up the creek is a *corridor for wildlife movement* and a place for marsh animals to find *refuge from high water and predators*. A managed pond with constructed islands adds *complexity to the landscape mosaic* of habitats, providing essential support for water birds. This *complete tidal wetland system* also includes a mudflat, barrier beach and oyster reef on the bay side, all of which *support greater biodiversity and physically protect* the adjacent marsh and shoreline. The marsh restoration in progress at the far right *uses dredged sediment* to allow the restored marsh to *achieve a higher elevation* prior to sea-level rise acceleration around midcentury, which will *better sequester carbon* and create a continuous corridor of marsh for wildlife movement along the shore. *Integrated management and monitoring* allows for thriving natural systems in close proximity to urban citizens.

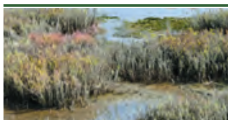
REGIONAL ACTIONS

Regional recommended actions are grouped below into 10 strategies to promote the long-term resilience of the baylands and their wildlife. An abbreviated version of each strategy is provided in the table below for easy reference, and the full description of each strategy follows the table. Each action is stated only once for brevity, even though some actions are interconnected and mutually supportive and could be placed under multiple strategies. The scientific rationale for the actions and other background information is provided in the Science Foundation chapters.

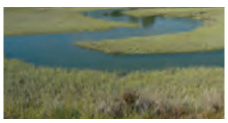
REGIONAL STRATEGIES TO PROMOTE RESILIENCE IN THE BAYLANDS LANDSCAPE, HABITATS, AND WILDLIFE

	**1.**	**Restore estuary–watershed connections that nourish the baylands with sediment and freshwater.**
	**2.**	**Design complexity and connectivity into the baylands landscape.**
	**3.**	**Restore and protect complete tidal wetlands systems.**
	**4.**	**Restore the baylands to full tidal action before 2030.**
	**5.**	**Plan for the baylands to migrate.**
	**6.**	**Actively recover, protect, and monitor wildlife populations to avoid bottlenecks and to buffer population sizes.**
	**7.**	**Develop and implement a comprehensive regional sediment-management plan.**
	**8.**	**Invest in planning, policy, research, and monitoring as key elements of implementing these actions effectively.**

9. **Develop a regional transition zone assessment program.**



10. **Improve carbon management in the baylands.**



1. Restore estuary–watershed connections that nourish the baylands with sediment and freshwater. (This follows from recommendation highlight 1 above.)

Take advantage of sediment transport processes in local rivers and streams that nurture the vertical accretion of tidal marsh, create alluvial fans, and create more riverine transition zones.

A. Prioritize tidal marsh restoration in areas with high sediment loads from local rivers and streams. Realign some stream courses where necessary and feasible to restore natural sediment-delivery processes. Protect land, working with willing sellers as needed.

B. Identify ways to increase the availability of watershed sediment to tidal marshes and mudflats. Develop a better understanding of watershed sediment-transport processes, including sediment storage, transport, and delivery to the baylands. Preserve and re-create natural patterns of sediment transport in local streams. Restore and protect local stream hydrology to provide the flow regimes necessary to move fine sediments to the bay while protecting stream health. Evaluate ways of accessing sediment trapped behind dams.

C. Use suitable sediment from various sources (excavated or dredged) for baylands restoration and management. Identify approaches to placing sediment that mimic natural accretion processes. Research and test innovative approaches for applying sediment to baylands, such as thin layers that do not cause unacceptable impacts to biological processes. Place sediment in volumes and frequencies that mimic natural processes.

D. Identify and implement opportunities for taking advantage of treated wastewater and stormwater to create salinity gradients and maximize peat accumulation in the baylands, while protecting water quality and minimizing nutrient loading. Accumulate peat in diked baylands prior to breaching to increase elevations and sequester carbon.

2. Design complexity and connectivity into the baylands landscape at various spatial scales (follows from recommendation highlight 2 above). Create a baylands landscape of diverse, complex, and connected habitat mosaics with patches of tidal marsh several hundred acres in extent. In the process of creating this landscape, consider how changes in habitat type due to climate change or restoration will affect different wildlife groups, and compensate for these trade-offs.

A. Connect large baylands habitat mosaics to each other and to local watersheds with a functionally connected transition zone around the perimeter and riverine riparian corridors that enable wildlife migration and dispersal. Restore and enhance gently sloped transition zones adjacent to tidal marsh and design them to support native wildlife species. Build naturalistic riverine levees as part of functionally connected riparian corridors along the bay's tributary streams to provide a high-functioning transition zone now and into the future. Incorporate agricultural land and managed wetlands as part of the matrix surrounding tidal wetlands.

B. Preserve or create high channel complexity in tidal marshes, or restore the processes that allow complex channels to develop. Complex channel networks have several orders of channel size, are sinuous, have a channel density appropriate to the local salinity regime, and exhibit point bars, slump blocks, undercut banks, and other physical attributes that create valuable habitat and natural water circulation that maintains high water quality. Where appropriate, provide large, deep channels in restored marshes for fish, invertebrates, diving and dabbling ducks, and other aquatic animals. Maximize the habitat value of channel complexity by promoting structurally diverse native vegetation to provide cover and high-tide refuge for wildlife such as Ridgway's rails.

C. Actively manage and restore diverse habitats for waterbirds and small mammals. Manage ponds in public ownership in the North and South Bay to maintain a range of salinities and water depths for waterbird foraging. Manage low-marsh vegetation, including native cordgrass) and establish beds of eelgrass, sago pondweed, widgeon grass, and native Olympia oysters to support waterbirds. Where possible, provide sufficient habitat for waterfowl, shorebirds, and small mammals by modifying managed ponds and taking advantage of opportunities to convert salt ponds to managed ponds and managed marsh. Ponds managed to support wildlife should be located in areas that facilitate operations and maintenance, as well as the long-term viability of the pond. They should also be located near other habitat resources (such as tidal mudflats for foraging) needed by the target species (generally waterbirds).

D. Reduce landscape barriers to wildlife movement by modifying roads, highways, levees and similar structures to allow the successful dispersal of native plants and animals, while proactively managing against the spread of invasive species and nuisance predators. Where feasible, create corridors of native plantings and open space through suburban and urban areas to make these areas more permeable and hospitable to native wildlife. For example, create species-appropriate passages for wildlife under or over freeways at critical points for habitat connectivity, and take advantage of opportunities to re-landscape parks and greenways to provide greater wildlife support.

3. **Restore and protect complete tidal wetlands systems** to provide habitat and physical resilience. Include all the following components appropriate to the local setting: submerged aquatic vegetation (SAV) beds, oyster beds, algal beds, rocky habitats, beaches, mudflats, low marsh, marsh plain, high marsh, complex channel networks, and transition zones, including natural levees along channels, creeks, and waterways, and broad transitions to adjacent wetlands and uplands.

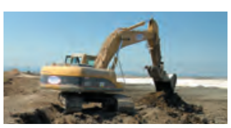
   A. Create high-water-refuge areas, including marsh mounds, restored and enhanced transition zones with appropriate vegetative cover, and diked wetlands where needed for wildlife such as salt marsh harvest mice.

   B. Provide buffers on undeveloped and agricultural lands (especially ones devoted to small grains, hay, and grazing areas) adjacent to the baylands to reduce disturbance and provide refugia from high water and other extreme conditions for wildlife, and to create the habitat mosaics needed for species that combine baylands and terrestrial habitats in their home range (e.g., northern harrier, dabbling ducks, and vernal pool species).

   C. Encourage where relevant the creation of appropriate wildlife habitats in developed areas adjacent to the baylands, and where feasible connect them through habitat islands and corridors to protected lands higher in the watersheds. Work with municipalities, land development companies, landscape architects, and others to incorporate habitat restoration, native plant landscaping, and other natural features that maximize support of baylands wildlife.

   D. Restore and create beaches, natural salt ponds, tidal marsh pans, and other diverse components of the baylands ecosystem to enhance wildlife support.

   E. Use restoration designs that integrate natural landscape characteristics and dynamics to maximize successful and sustainable outcomes and increase resilience, while minimizing long-term operational and maintenance costs.



4. **Restore the baylands to full tidal action before 2030** in strategic areas to maximize marsh accretion before the expected acceleration in sea-level rise and to sequester carbon sooner rather than later.

   A. Consider available information, including local sediment supply, erosion regimes, marsh-accretion models, and landscape position, to prioritize areas for restoration that are likely to persist as marsh for many decades.

   B. Accelerate funding and streamline the implementation of projects that restore the baylands to tidal action.

   C. Encourage baylands restoration as an outcome of, and a reason to accelerate, the realignment of infrastructure at risk from sea-level rise, including railroads, transmission lines, roads, fuel lines, and wastewater treatment systems.

5. **Plan for the baylands to migrate** by using projections of sea-level rise and other changes to identify shifts in habitat location and connectivity over time. Encourage the implementation of relevant recommendations from this report as part of plans for upgrading levees, railroads, highways and other roads, bridges, wastewater treatment plants, utility corridors, and other public works infrastructure that will affect outcomes in the baylands.

   A. Identify and protect existing and projected transition zone lands or flood easements. Focus on broad, minimally developed areas adjoining existing tidal marshes that support high native-species diversity or are wildlife source habitats. Prioritize areas projected to retain biodiversity across a range of future climate scenarios. Plan ahead for the likelihood that, as sea levels rise and transition zones become marsh, there will be a loss of transition zone habitat for sensitive species, such as vernal pool wildlife and burrowing owls.

   B. Inventory intact patches of wetland and nonwetland habitat types that adjoin the present transition zone, including grasslands, seasonal wetlands, and forests. These should be fully protected to prevent further degradation and a loss of transition zone extension and enhancement opportunities.

   C. Identify the habitat patches likely to be used in the future for a suite of umbrella species and other species of concern. Establish movement corridors between current habitat patches, and plan how to ensure connectivity to future habitat patches. Design corridors for intermittent or permanent connectivity that minimize the impact of nuisance predators and invasive species. Prioritize the connectivity of patches that can provide recruits or propagules to move into new areas as they become suitable. Compensate for habitat loss due to climate change in one area by providing it in another (for example, if mudflats are lost in one area, encourage mudflat formation elsewhere for use as harbor seal haul-outs).

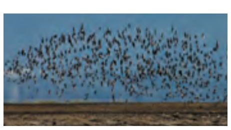
   D. Conduct a large-scale, long-term planning effort across the bay, delta, Central Valley, and other key areas of California to ensure that waterbirds that use the Pacific Flyway have sufficient habitat over the coming decades. Planning for restoration and conversion of waterbird habitats should be coordinated, so that

View of Salt Pond A20, which was restored to tidal flow in 2006

Salt pond breach

an optimal landscape (considering financial cost, habitat benefit, and implementation feasibility) can be pursued at the large scale that is biologically relevant for these highly mobile animals.

E. Encourage the modification and relocation of existing assets and infrastructure that are in the present and future flood-hazard zone to allow the reestablishment of physical processes such as full tidal flows. Discourage the development of new assets and infrastructure in present and future flood-hazard zones, as they may constrain restoration and other adaptation options that may help protect adjacent communities. Build in designs that allow wildlife to pass over, under, or through areas of infrastructure development to promote habitat connectivity and gene flow.



6. **Actively recover, protect, and monitor wildlife populations to avoid bottlenecks and to buffer population sizes** against extreme events. The regional actions recommended in this section should benefit wildlife by enhancing their habitats and the ecological functioning of the landscape as a whole. In addition, the actions below are specific recommendations for managing the wildlife populations themselves. As a rule, invasive or hands-on wildlife management (such as the lethal control of native predators and the translocation of individuals) should be pursued only as a last resort, after other solutions based on habitat and natural-process improvements have been implemented and found to be insufficient. There will likely be trade-offs between managing for different species, and taking action will require careful judgment of these trade-offs.

A. Emphasize protection efforts during and after extreme weather or other events that may cause population crashes.

- Emphasize nonnative and nuisance-predator control during and following times of short-term, stressful climatic conditions.
- In critical areas, construct systems that impede water flows for short time periods to reduce high water levels in times of acute stress.
- Monitor indicator species more frequently to know when and where such intervention is warranted. Use a rigorous process to identify key indicator species for the baylands to enable coordinated and comprehensive monitoring across the region.

B. Provide appropriate breeding and refuge habitat for species that need targeted management.

- Identify, conserve, and manage refugia for native baylands plants that may otherwise lose significant habitat due to sea-level rise. Focus on unique or core populations of rare or endangered species, especially in low marshes.
- Manage or create vernal pools of various sizes, depths, and salinities to facilitate a metapopulation structure for vernal pool plants and animals. Inoculate pools with nearby source populations of shrimp species and amphibian tadpoles. Control weeds and seed pools with vernal pool vegetation for several years until established.
- Provide spawning areas for fish, particularly open sandy beaches for grunion and clean, rough substrates in brackish waters of appropriate salinity for Pacific herring. Consider removing creosote pilings, and build new marine structures in the Suisun and San Pablo Bays with roughness, light availability, and other environmental characteristics in mind.
- Ensure that suitable ponds are appropriately inundated throughout the reproductive season for amphibians, with a focus on the needs of California red-legged frogs and California toads. Infrastructure, such as wells and pumps or water lines, may be necessary to provide additional water to ponds.
- Manage islands and levees and adjacent water levels to provide nesting, foraging, roosting, and high-tide-refuge habitat for birds. Add nesting substrate (such as sand and shell) to islands in the South Bay and, potentially, Suisun Bay for shorebirds. Minimize changes in water levels in seasonal wetlands during the breeding season to avoid flooding nests.

C. Maintain and enhance genetic diversity using active management when the passive landscape-design methods described earlier are insufficient.

- Translocate species requiring assistance (such as tidewater gobies or shrews) into newly created habitats or into formerly occupied patches after an extreme event causes extirpation.

- Assist the dispersal of high-marsh annual forbs and dispersal-limited or founder-limited populations of uncommon baylands plants of the high-marsh and transition zone to unoccupied locations near historic or existing populations. Assist their dispersal to restored marshes before nonnatives invade to facilitate their recovery after invasive species are eliminated, and keep seed sources restricted to local or subregional origin.
- Acquire more information about the genetic structure of baylands species with limited dispersal ability, including the ways that landscape barriers and corridors influence gene flow.

D. Reduce excessive predation impacts to sensitive species by managing nonnative and problematic native predators (such as red fox, cats, California gulls, crows, and ravens), and reducing predator access.

- Use integrated pest-management techniques over an appropriate time period, which is often the entire breeding season. Reduce impacts from cats by educating cat owners and working with animal shelters and trappers to remove feral cat feeding stations to areas of least impact and to handle nuisance animals properly. Emphasize mosquito-source-control methods based on natural physical and biological processes such as wind-generated waves and ripples, tidal flushing, and foraging by native insectivores. Minimize mosquitofish plantings during the California red-legged frog breeding season and avoid mosquitofish use in sensitive amphibian habitat.
- Remove or modify features that facilitate predator access to, and hunting in, the baylands (such as derelict fencing and utility towers used as perches by raptors). Reduce access from levees and other upland areas, and design any new levees to impede predator access. Where feasible, eliminate garbage dumps near the baylands. Provide cover from predators, especially during periods of exposure (e.g., extreme tides).

Plainfin midshipman

E. Manage and eliminate invasive plants, and use preventive measures in restoration projects and future transition zones. Avoid persistent soil-active herbicides that jeopardize seed banks of desirable plant species. Consider and minimize impacts to marsh fauna (including black rails, baylands shrews, and salt marsh harvest mice) from control measures.

Native gray fox

- ▹ In the near term, complete the elimination of invasive *Spartina* phenotypes (plants that act in the environment like the invasive hybrid), and prevent their reemergence. Where invasive phenotypes persist, focus efforts on lessening the impacts of invasive characteristics while promoting the long-term development of in-marsh structural complexity and native plant species abundance and diversity.
- ▹ Contain perennial pepperweed, and eliminate populations near the transition zone. Control pepperweed to prevent its spread into mature brackish tidal marshes that are not yet heavily infested.
- ▹ Aggressively control yellow flag, black rush, and Algerian sea lavender before they become a serious problem.

F. Reduce other stressors, mainly human disturbance and contaminant exposure.

- ▹ Design and manage recreational access to avoid and minimize disturbance to wildlife, especially during critical periods of their life cycle, such as nesting seasons, and during extreme high tides.
- ▹ Reduce wildlife exposure to contaminants, including methylmercury, pyrethroids, polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), and other organic contaminants.

7. Develop and implement a comprehensive regional sediment-management plan, building on existing regional sediment-management work that emphasizes the use of all suitable dredged or excavated sediment from the estuary, local rivers and streams, flood-control channels, local reservoirs, and other watershed sources. This comprehensive sediment-management system should be developed in close partnership with the bay dredging community.

A. Conduct research and monitoring to quantify (1) all potential sediment sources to the baylands, in particular their magnitude and spatial and temporal patterns of delivery, and (2) sediment transport and fate dynamics in baylands ecosystems, particularly mudflats and marshes.

B. Investigate if there will be enough sediment to maintain current marshes, mudflats, and managed ponds under specified sea-level rise projections and sediment-supply parameters, including local and Central Valley watersheds, until

2070 and 2100. In considering this question, studies should address the following scenarios:

- currently planned tidal marsh restoration
- the additional acreage needed to reach the 100,000-acre Baylands Goal for tidal marsh
- maintenance over time of the acreage goals for managed ponds
- planned restoration in the delta (specifying acreage, bathymetry, timing)
- potential extensive levee failure in the delta, Suisun, or North Bay
- beneficial reuse of all suitable dredged sediment from the estuary
- beneficial reuse of suitable excavated dirt from the watershed
- increasing watershed sources of sediment to the baylands (such as accessing sediment behind dams and other watershed management approaches)

C. Manage coarse bay sediment at the regional level for use in the baylands. Allow sand to move through the bay under natural forces to create and replenish barrier beaches.

8. Invest in planning, policy, research, and monitoring as key elements of implementing these actions effectively (follows from recommendation highlight 3 above).

A. Revisit these recommendations every 10 years and issue updates based on the understanding that has developed through research and adaptive management in the intervening time.

Active revegetation at Cogswell marsh

B. Develop designs and implementation plans for the management and restoration of large stretches of baylands to maximize the positive synergies among individual projects. Identify the appropriate boundaries of these areas based on the scale of natural processes, such as watersheds or patterns of sediment deposition and erosion along shorelines.

C. Adapt current policies to allow for the development and application of new, environmentally safe approaches that increase the ecological resiliency of the baylands. Existing regulations and policies have limitations on the use of bay fill to create habitat and on the reuse of dredged material. They also do not include specific recommendations or best management practices for new techniques such as sediment placement or the use of shells and other materials for subtidal restoration, horizontal levees, and improvements (like creosote removal or encapsulation) to living seawalls, living docks, and other existing infrastructure. Thoughtful experiments and data analyses of the new approaches listed here are needed, which will mean changes to existing policies and regulations.

D. Consider all the elements of complete tidal wetland systems (including mudflats, the transition zone, and adjacent subtidal and terrestrial habitats) to be integral parts of baylands restoration at all scales, and encourage their inclusion in relevant regulatory framework and planning efforts.

E. Develop compatible approaches to baylands conservation for wildlife, public recreation, and traditional indigenous uses. Limit or restrict public access to areas with sensitive wildlife habitat value, particularly during breeding seasons. Where appropriate, provide access for wildlife-dependent activities such as fishing, hunting, wildlife observation, wildlife photography, interpretation, and environmental education. Develop other compatible public access in appropriate locations. Provide interpretive signage describing habitat values and promoting proper wildlife-viewing etiquette.

F. Ensure the continuity of programs to detect, manage, and eliminate invasive species. Establish and implement early-detection, rapid-response plans for novel outbreaking populations of invasive plants and animals to prevent their spread. This could be accomplished by reinitiating the Bay Area Early Detection Network (BAEDN) or providing similar capacity. Develop adaptive strategies for anticipated or newly arrived invasive species, including those that arrive because of climate-driven range shifts. Anticipate and prepare for the consequences of the impending invasion of the estuary by quagga and zebra mussels.

G. Conduct research and modeling to answer key science questions that will affect management decisions. One initial effort should be to model planned tidal restoration throughout the bay and delta, as well as changes to precipitation and reservoir operations, in order to estimate future salinity regimes and hydrodynamic changes.

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9. **Develop a regional transition zone assessment program** as part of the actions described in recommendation highlight 3.

   A. Develop a collaborative program of potential transition zone site assessment, project tracking, performance evaluation, applied research, and public reporting. Consider basing the program on the Wetland and Riparian Area Monitoring Plan and the tool set of the State Water Resources Control Board. The assessment program should, at the outset, provide a map of the full extent of transition zones as defined in the report, structured in a way that it can be updated as needed. The program should also allow local agencies to contribute to the updates. Methods to assess the existing and restored transition zone should be standardized, such that projects can be compared with each other and with background or ambient conditions over time. Information about the location and status of transition zone restoration projects should be readily available online, and the overall condition and prognosis of the transition zone throughout the region should be regularly explained to the public.

   B. Establish a standing team of technical experts through an independent science organization to give advice on transition zone design, restoration, management, and assessment, such that these efforts are consistent with this and future updates of the Baylands Goals.

C. Develop a comprehensive portfolio of strategies for the conservation, restoration, and management of various transition zone types.

- Aim for consistency with natural landscape characteristics and dynamics in order to restore high levels of transition zone services when selecting and designing transition zone components. These include vernal pools, other seasonal depressional wetlands, moist grasslands and other slope wetlands, riparian forests along streams, tidal marsh, natural salt ponds, barrier beaches and berms, dunes, and shallow lagoons.
- Where appropriate, partially fill diked baylands and consider filling subtidal areas to create a transition zone on the bay side of levees.
- Develop methods to prepare terrestrial areas that will become transition zones. Conduct applied research on ways to encourage tidal-channel formation, topographic complexity, and native plant communities of the transition zone. Develop guidance for improving the management of agricultural baylands as an existing and future transition zone.

Slough channel and mudflats at sunset

10. **Improve carbon management in the baylands** to prevent further subsidence, increase organic matter accumulation, reduce greenhouse gas emissions, and sequester more carbon.

    A. In appropriate areas of managed freshwater marshes, promote the accumulation of belowground carbon by enhancing plant productivity while maintaining anaerobic soil conditions to inhibit decomposition. This can be achieved by gradually raising water levels. Maintain soil salinities close to 18 ppt to reduce the likelihood of methane emissions.

    B. On diked baylands with organic soils that are drained permanently or seasonally, raise the water tables to reduce soil carbon loss, fill ditches to reduce methane emissions, and reduce fertilizer or cattle densities, if appropriate, to reduce soil methane and nitrous oxide emissions.

    C. Develop approaches to make use of compost from recycled food waste, possibly integrated with wastewater disposal, on diked and other baylands as appropriate.

    D. Conduct applied research to inform better carbon and greenhouse gas management as a part of baylands restoration designs and management approaches. Quantify the greenhouse gas emissions from baylands of different habitat types, land uses (including all drained organic soils), and water-management regimes across the salinity gradient. Focus in particular on drained wetlands in Suisun, where peat is likely to be oxidizing and causing subsidence. Measure soil depths in current wetlands across the estuary so that existing pools of soil organic carbon can be calculated. Improve the understanding of the fate of carbon and nitrogen released from eroding tidal wetlands.

    E. Develop a more detailed plan for prioritizing activities to incorporate climate change mitigation into baylands management.