Climate-Smart Adaptation for North-central California Coastal Habitats

Report of the Climate-Smart Adaptation Working Group of the Greater Farallones National Marine Sanctuary Advisory Council

Editor: Sara Hutto

March 2016

Report Citation

Hutto, S.V., editor. 2016. *Climate-Smart Adaptation for North-central California Coastal Habitats.* Report of the Climate-Smart Adaptation Working Group of the Greater Farallones National Marine Sanctuary Advisory Council. San Francisco, CA. 47 pp.

Cover photos

(left) Bolinas Lagoon seawall, Eric Hartge, Center for Ocean Solutions, (right) Rocky intertidal at Point Arena, David Ledig, BLM/California Coastal National Monument, (bottom): Rodeo Beach, NPS

This work was made possible with support from:

Working Group Members

Chair:
Anne Morkill, US Fish and Wildlife Service; Greater Farallones National Marine Sanctuary Advisory Council

Sarah Allen, National Park Service Pacific West Region
Debbie Aseltine-Neilson, California Department of Fish and Wildlife
Kate Bimrose, Greater Farallones Association
Marlene Finley, San Mateo County
Joel Gerwein, California State Coastal Conservancy
Eric Hartge, Center for Ocean Solutions, Stanford University
Daphne Hatch, Golden Gate National Recreation Area
Maya Hayden, NOAA Sentinel Site Cooperative
Deborah Hirst, San Mateo County
Jaime Jahncke, Point Blue Conservation Science; GFNMS Advisory Council
Joanne Kerbavaz, California State Parks
Irina Kogan, San Mateo County Resource Conservation District
David Ledig, Bureau of Land Management
Jack Liebster, Marin County
Mary Matella, California Coastal Commission
Shannon Fiala, California Coastal Commission
Gerry McChesney, US Fish and Wildlife Service
Andrea O'Neill, US Geological Survey
Hilary Pappendick, San Mateo County
Brenna Rudd-Mahoney, California State Coastal Conservancy
Kristen Ward, Golden Gate National Recreation Area
James Weigand, Bureau of Land Management
Alex Westhoff, Marin County

Technical Experts

John Largier, Bodega Marine Laboratories, UC Davis; GFNMS Advisory Council
Andrew Gunther, Bay Area Ecosystems Climate Change Consortium

Staff to the Working Group

Lara Hansen, EcoAdapt
Sara Hutto, Greater Farallones National Marine Sanctuary
Karen Reyna, Greater Farallones National Marine Sanctuary
Whitney Reynier, EcoAdapt
Sam Veloz, Point Blue Conservation Science

Table of Contents

Executive Summary

The North-central California coast and ocean is a globally significant and extraordinarily productive marine and coastal ecosystem that boasts an array of local, state and federal protected areas and other managed lands. Despite this richness and attention to conservation, this region is still vulnerable to the effects of climate change. The Greater Farallones National Marine Sanctuary Advisory Council (Council) convened the multi-agency Climate-Smart Adaptation Working Group (Working Group) in response to the need to develop climate-smart adaptation strategies to enable coastal and marine resource managers to respond to, plan, and manage for the impacts of climate change. Working Group members sought to provide strategies to help ensure long-term viability of the species and habitats natural resource agencies are mandated to protect, and the public values. Building on Phase 1 of the Greater Farallones National Marine Sanctuary's Climate-Smart Adaptation Project that assessed vulnerability to climate and non-climate stressors for select species, habitats, and ecosystem services, the Working Group undertook a yearlong multi-agency process to develop the climate-smart adaptation strategies presented in this report. The strategies were presented to the Council for discussion, modification, and approval, and forwarded to the Sanctuary Superintendent for consideration in current or future adaptation planning efforts.

The Council Working Group developed 50 priority strategies and 28 lower priority strategies in 10 categories, including Alleviate Climate Impacts, Manage Dynamic Conditions, Promote Education, Protect and Restore Habitat, Limit Human Disturbance, Address Invasive Species, Promote Landward Migration, Invest in Science Needs, Protect Species, and Manage Water Quality. Strategies were also characterized in terms of timeframe, location, strategic management action, stressor addressed, key partners and required resources.

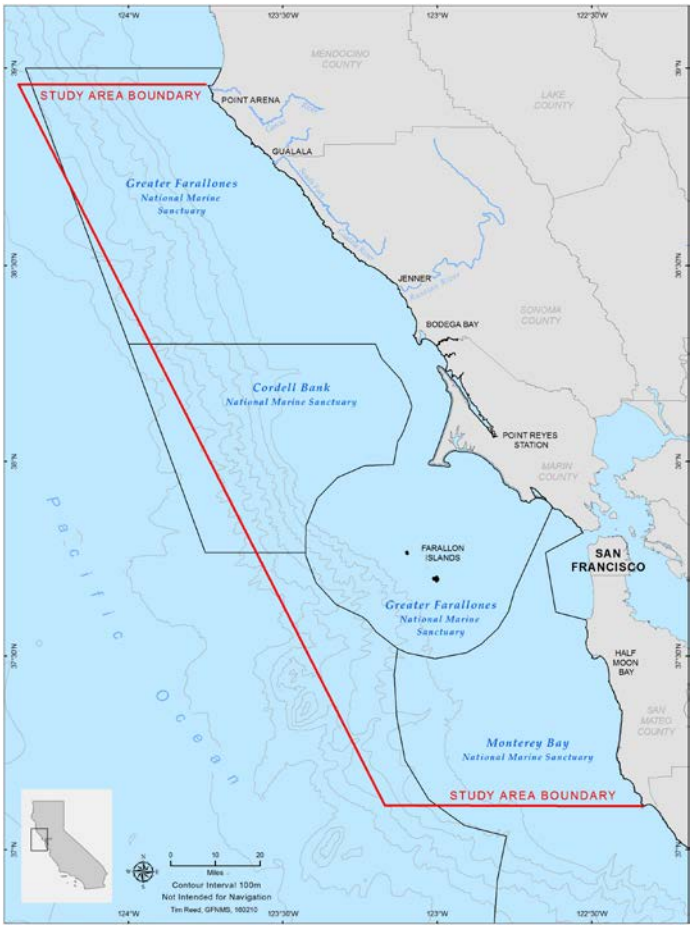
While there is much work on tropical marine adaptation action, temperate regions to date have had many fewer resources. The Council Working Group's contribution aims to turn this tide and begin a wave of implementation of climate-smart temperate coastal and marine management.

Introduction

Project Background

The North-central California coast and ocean is a globally significant, extraordinarily diverse and productive marine and coastal ecosystem that is home to abundant wildlife, valuable fisheries, two national marine sanctuaries, two national parks, a national wildlife refuge, a national monument, multiple state parks and state marine protected areas, and two international RAMSAR estuaries. This coastal region is a treasured resource of the San Francisco Bay Area's seven million residents that rely on this unique marine ecosystem for their livelihoods and recreation. Significant coastal areas, including Tomales Bay, Bolinas Lagoon, Fitzgerald Marine Reserve, Point Reyes Headland, Drakes Estero, Pescadero Marsh, Duxbury Reef and the Farallon Islands, support a diversity of habitats, including eelgrass beds, intertidal rocky benches, sand and mud flats, salt and freshwater marshes, and extensive beaches and dunes. These habitats also provide numerous ecosystem services such as carbon storage, flood and erosion protection, and improved water quality. Offshore islands, rocks, and coastal cliffs provide critical nesting, haul-out, and roosting areas for the largest concentrations of seabirds and marine mammals on the West Coast outside of Alaska.

Natural resource managers realize the imminent threats of climate change to the health, sustainability, and ecosystem function of the special coastal and ocean places they protect, yet the capacity to develop appropriate management options to prepare for and respond to a changing environment are limited (Gregg *et al.* 2011). Adaptation planning techniques and processes are well developed, but there is a lack of application of these methods for marine systems (Gregg *et al.* 2011). The Greater Farallones National Marine Sanctuary Advisory Council (Council) convened the multi-agency Climate-Smart Adaptation Working Group (Working Group) in response to this need to develop climate-smart adaptation strategies to enable coastal and marine resource managers to respond to, plan, and manage for the impacts of climate change to habitats,



species, and ecosystem services within the North-central California coast and ocean (Figure 1). Specifically, project partners seek to integrate climate-smart adaptation into existing management frameworks, and provide guidance to help ensure long-term viability of the species and habitats natural resource agencies are mandated to protect and the public values.

This effort builds from Phase 1 of the Greater Farallones National Marine Sanctuary (Sanctuary)'s Climate-Smart Adaptation Project that assessed vulnerability to climate and non-climate stressors for select species, habitats, and ecosystem services in the region through two decision-support workshops (Hutto *et al.* 2015 and available here). The climate-smart adaptation strategies presented in this report are a result of a yearlong multi-agency process to develop management responses to the vulnerabilities identified in Phase 1. These strategies will be presented to the council for acceptance, and then forwarded to the Sanctuary Superintendent as well as other coastal resource management agencies in the region, such as National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, California State Parks, California Department of Fish and Wildlife and Counties of San Mateo, San Francisco, Marin and Sonoma, for consideration in their current or future adaptation planning efforts.

Working Group Goal:

Develop and prioritize climate-smart adaptive management strategies that can be feasibly implemented by managers to reduce the vulnerability of select focal resources, while considering a range of plausible future climate scenarios for the region.

Working Group Objectives:

1) From the focal resources assessed in Phase 1 (available here), select those that should be the focus of adaption planning.
2) Develop distinct, plausible future climate scenarios for the region to serve as a framework for adaptation planning (Appendix A).
3) Based on the vulnerability assessments, develop issue statements and management goals for focal habitats (page 5).
4) Develop adaptive management strategies for each habitat under all climate scenarios.
5) Finalize and prioritize management strategies across habitats (pages 10-31).

Methods

Working group authority

Working groups are established under the Council, whose purpose is to provide community and interagency stakeholder advice to the Sanctuary Superintendent on a variety of Sanctuary management issues. The Council can establish working groups for specific purposes or topics that need focused attention that cannot otherwise be accomplished by the full Council. Working groups may be composed of members of the Council and persons outside the Council, be chaired by a primary member of the Council, and shall function under the purview of the Council. The opinions and findings of a working group and the Council do not necessarily reflect the position of the Sanctuary, the National Oceanic and Atmospheric Administration, or the agencies and organizations working group members represent.

Working group process

At the August 2014 meeting of the council, project staff presented the results of the vulnerability assessment from Phase 1 of the Climate-Smart Adaptation Project (Hutto *et al.* 2015), and requested the formation of a working group to develop and prioritize management actions in response. The Council voted to convene this working group and selected Anne Morkill, USFWS, as working group chair. In December 2014, based on expertise and jurisdictional boundaries, representatives from local, state, and federal agencies, non-profit organizations, and academic institutions were invited to serve on the Climate-Smart Adaptation Working Group. The Working Group was staffed and advised by representatives from the Sanctuary, as well as members of the scientific and conservation community in order to provide invaluable information used during the working group's deliberations, enabling the group to formulate practicable strategies. The Working Group held five meetings from April through December 2015 in Oakland, as well as numerous conference calls and online collaborations. This document is the result of those efforts.

Meeting summaries

Scenario Planning (April 22, 2015)

At their first meeting, Working Group members discussed the results of the vulnerability assessment and selected the resources they would consider in adaptation planning. The group decided to plan for the three most vulnerable habitats in the region (as identified in the Phase 1 vulnerability assessment):

- Beaches and dunes,
- Rocky intertidal, and
- Outer coast estuaries,

with the understanding that benefits from the adaptation strategies would extend to the vulnerable species and ecosystem services associated with these habitats. Cliffs were also included in association with beaches/dunes habitat due to the importance of this habitat to

nesting seabirds. Sam Veloz, staff to the Working Group, led members through a scenario planning exercise, using the vulnerability assessment results and the Scenario Planning for Climate Change Adaptation guide (Moore *et al.* 2013). Scenario planning is a successful and flexible approach to incorporate climate uncertainty into decision making to develop adaptation actions for multiple, plausible climate futures, and is especially useful when critical drivers of change are highly uncertain and cannot be controlled (Moore *et al.* 2013). Members evaluated drivers of change that were identified in Phase 1 as contributors to focal resource vulnerability and ranked those drivers by their relative uncertainty (in future direction and magnitude of change) and importance to management decisions. The Working Group selected the three most uncertain/impactful drivers of change (precipitation, wave action, and upwelling), and from those created 12 potential climate futures for the study region. The group discussed the implications of the three scenario drivers to each of the habitats of interest and did an initial brainstorming session of likely management responses to these drivers of change. They were not able to pare the 12 scenarios down to a more manageable number, so they tasked staff to work with technical advisors John Largier and Andy Gunther to determine how best to move forward with identifying four distinct and robust climate scenarios from the initial 12 proposed scenarios.

Refining Scenarios and Developing Management Goals (May 27, 2015)
At their second meeting, the Working Group heard an update from Sam Veloz regarding the development of four final climate scenarios for the region, from the original 12 proposed by the group. Sam presented a "straw man" proposal from John Largier to develop four scenarios from the drivers of upwelling and run-off. The Working Group discussed these new drivers and approved of the resulting scenarios, then developed titles and headlines to describe these future scenarios and the impact they may have on the North-central California coast and ocean region. Four Working Group members volunteered to help staff write up summaries for each scenario (Appendix A) in preparation for the group's next meeting. Lara Hansen, staff to the Working Group, gave a presentation regarding adaptation planning and discussed the process and methodology for successful development of adaptation strategies.

Based on interest and expertise, Working Group members organized into habitat teams for the remainder of the meeting to develop the following management goals for each habitat:

- Beaches and Dunes: Maintain functional stability and protect and enhance the ecological integrity of the beach and dune environment both under present and future conditions.
- Cliffs: Protect existing cliff habitat from accelerated degradation.
- Rocky Intertidal: Ensure that viable and ecologically functioning rocky intertidal habitat remains present in the study region.
- Outer Coast Estuaries: Optimize physical and biological function and processes of outer coast estuaries under present and future conditions.

Adaptation Planning (September 15, 2015)

After a summer hiatus, the Working Group came together for the third time to begin adaptation planning, using the scenarios and management goals they had developed at previous meetings and resources developed by staff to aid in the process. The scenarios that were approved at the May meeting were detailed by Working Group volunteers and staff over the summer, and the habitat-level impacts of these scenarios were presented and discussed. The remainder of the meeting was spent in habitat teams, developing management strategies in response to the four climate scenarios. The goal of the scenarios was to encourage Working Group members to move past uncertainty in future conditions to develop adaptation strategies. In general, the habitat teams realized that good strategies will make sense regardless of which scenario may occur in the future and were not at all constrained by uncertainty in their planning exercise. The scenarios were helpful to visualize potential future impacts but ultimately were not needed by the Working Group after this meeting. Adaptation planning resources available to the Working Group during this and subsequent meetings included a summary table of marine and coastal adaptation strategies being implemented across the United States (sourced from the Climate Adaptation Knowledge Exchange) and regional maps detailing jurisdictional boundaries to facilitate spatially informed adaptation planning.

Adaptation Strategy Development (October 16, 2015)

At their fourth meeting, the Working Group continued the development of management strategies in their habitat teams. The teams focused on providing as much detail to the strategies as possible, and brainstormed new and innovative responses to climate impacts. At the end of the day, all teams reported back to the large group and agreed that a conference call for each habitat team would be needed in order to finish the development of their recommendations. These conference calls took place in November.

Adaptation Strategy Prioritization (December 3, 2015)

At their final meeting, the Working Group spent an hour in their habitat teams to address any additional information needs for the strategies and to analyze any that may be combined or removed from the final list. The teams then underwent a prioritization exercise, using the following criteria to rank the strategies in order of priority:

1) Consistency with project goal (protect and maintain healthy ecosystems by enhancing the resilience of resources) and individual habitat goals;
2) Co-benefits (e.g., to infrastructure, economy, recreation);
3) Consistency with existing laws and policies;
4) Feasibility (cost and institutional capacity);
5) Efficacy in reducing identified vulnerabilities;
6) Climate-Smart:
    - Addresses near-term and long-term changes
    - Robust to uncertainty (i.e., applies to multiple scenarios)

- Minimal carbon footprint
- Adaptive and flexible, can respond to change
- Avoids maladaptation and unintended consequences
- Provides mitigation benefit (sequesters carbon)

7) Urgency (i.e., needs to be implemented or started soon in order to see benefits)

Habitat teams presented their highest priority strategies back to the large group (those ranking 2.5 or higher on a 1-3 scale), and the group identified overlapping and conflicting strategies across habitats and asked questions of other habitat teams. The Working Group decided to include all final strategies in their report, but to highlight those that were identified as "high priority" through this prioritization process. There was some discussion regarding process and a timeline for next steps for the Working Group to finalize their management strategies and final report to the Council.

Council Meeting (March 2, 2016)

At the conclusion of the working group's meetings, staff and the Working Group chair prepared the strategies and drafted a report for Council review and approval at their March 2nd meeting. At this meeting, the Council reviewed each individual strategy, provided edits and revisions, and voted on the strategies by approach category with the following motion:

> The GFNMS Advisory Council recommends the sanctuary consider the "[insert approach category]" strategies identified for the sanctuary, and for the strategies identified for other agencies, the Council recommends that the sanctuary superintendent forward them to the appropriate agency.

Those final strategies are included in this report, and a content-protected excel file is attached as Appendix D.

Potential Management Strategies

Potential management strategies developed by the Working Group are presented by overall approach. Strategies that identify the Sanctuary as a key partner are highlighted and listed first under each approach category. Within these groupings, strategies are then listed by the timeframe indicated, with near-term strategies listed first. Priority management strategies are listed in the first table, with the remaining, non-priority strategies following in a second table. The non-priority strategies may still be potential adaptation actions to consider based on different management needs and goals. In addition, these actions may become more feasible and effective in the future if uncertainties are addressed via research. Appendices B and C include descriptions of key terms and agency designations found throughout the strategies. Strategies are also included in Appendix D as a sortable, content-protected excel file to enable users to sort by column and search by key word. Appendix E presents successful case studies of coastal and marine adaptation, compiled by EcoAdapt. It is the intent of the Working Group to provide these potential management strategies as a reference for management agencies in the region to reduce the vulnerability and increase the resilience of coastal habitats in response to increasing impacts from a changing climate. This also presents an opportunity for agencies and organizations to share, communicate, and collaborate to assess, improve and implement these strategies.

These strategies do not represent the entirety of what can be implemented to reduce vulnerability of coastal resources and do not provide detailed recommendations for individual projects. These strategies represent the ideas generated through a diverse and collaborative effort to identify potential actions that could be taken by natural resource management agencies to address climate change. Application of these strategies will require additional legal and methodological considerations by the implementing agency on a case-by-case basis. It is ultimately the Council's decision to convey these strategies as recommendations to the Sanctuary Superintendent for consideration. These strategies do not necessarily represent the positions of affiliated agencies or organizations, have not been vetted by those organizations, and reflect the opinions and ideas of the Working Group members themselves.

The Working Group recommends that regional partners consider the following as they view and reference this effort:
1) All strategies should be implemented with metrics for monitoring and evaluation of efficacy.
2) Some strategies identify new or novel ideas that either have not been tested or have not been tested in the context recommended; therefore, these ideas may require a demonstration project and/or research on viability and the mechanism for implementation.
3) Some strategies are more general in nature or are presented in a simplified context. These will require additional detail depending on the agency and location of implementation.
4) Sanctuary staff should ensure that the correct implementing agencies are identified for each strategy, and make these strategies available to all agencies identified.

Table Legend

Approach: The general method for reducing habitat vulnerability and the descriptive identifier for the type of strategy.

Strategic Management Action: The implementable and specific action to be taken to accomplish the approach (e.g. restrict public access through signage, closure zones, and enforcement in order to protect sensitive habitat).

Spatial or site-specific details: If applicable and possible, the strategy includes potential locations for strategy implementation (i.e. Bolinas Lagoon), and/or spatial characteristics for which the strategy would be appropriate (i.e. sediment-starved estuaries).

Timeframe: Immediate (implement as soon as possible), near-term (by 2025), mid-term (by 2050), long-term (by 2100)

Stressor(s) addressed: Of the stressors addressed by the Climate Change Vulnerability Assessment Report (Hutto *et al.* 2015), the major climate or non-climate stressors that are being targeted and alleviated by this strategy. See "Climate Factors for the Study Region" on page 12 of the Assessment Report for description of climate stressors, and the methodology section on page 17 for non-climate stressors.

Key partners: All agencies, organizations, academic institutions and others that would need to be part of successful implementation. Some strategies indicate the ideal lead for implementation.

Required resources: The resources required for implementation, including staffing, funding, information, collaboration, and community or political support.

Notes: Any additional details that do not directly fit in the other columns, including methodology details, potential interactions with other habitat types, potential conflicts, consequences, benefits of the strategy, and required cooperation.

Priority Strategies (highlighting indicates strategies identified for Sanctuary implementation)

Manage Dynamic Conditions: strategies that are responsive and adaptive to changing conditions

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
1	Add or relocate sediment to areas that are sediment-starved in estuaries and wetlands to help keep pace with sea level rise.	Sediment-starved areas in estuaries, or where needed.	Near-term	sea level rise, sediment supply	Sanctuary in partnership with Army Corps of Engineers and other sediment suppliers.	May be able to use dredge materials. There must be a process to ensure quality sediment is used. Incorporate into a larger, watershed-specific sediment management strategy. CCC permit or federal consistency review.	Creates/maintains habitat area and function in the face of sea level rise. Potential issues with TMDLs.	estuaries
2	In areas dominated by grey infrastructure, identify potential demonstration sites for green infrastructure projects and/or other "active management" projects; implement and evaluate effectiveness to inform future efforts across the region. Potential project options include: - Use wastewater treatment plants to supply fully treated and advanced wastewater for estuaries where benefit can be demonstrated. - Build a horizontal levee in threatened part of sanctuary (e.g., estuary that is flood-prone or needs additional habitat) - Install bioswales near areas dominated by infrastructure/roads - Install rain gardens with soil layers engineered to help stormwater infiltrate underlying layers of soil -Find ways to allow larger passage for high flow events	Site-specific: location and method/project will be determined by issues in each specific estuary Prioritize estuaries currently impacted by flooding/storms, and in locations where the project could have co-benefits for other systems or human communities	Near-term	precipitation, sea level rise, coastal erosion, wave action	Sanctuary and estuary managers (possibly Marin County Parks, State Parks, NPS, Sonoma County Parks) in partnership with universities.	Funding required for initial project implementation as well as monitoring after implementation - consider NSF and foundations. Monitoring framework. CCC permit or federal consistency review.	There are many unknowns in how to manage for estuaries; this action will test different strategies and help innovate management, with the goal of helping sustain estuary habitat. Could have negative impacts (e.g., loss of tidal mudflat habitat). Need to balance risks	estuaries
3	To the extent practicable, reduce or modify armoring that exacerbates erosion; replace or enhance with natural material to create sloped, transitional habitat (e.g., artificial reef or dune). If armoring can't be removed and replaced, implement living shoreline techniques in conjunction with new construction/repairs.	Potential locations: Bolinas Lagoon (on lagoon side of the spit), Seadrift on Stinson Beach, Tomales Bay, Sonoma County along Hwy 1, Russian River	Mid-term	overwater/under water structures, roads/armoring, coastal erosion	Sanctuary and estuary managers (possibly Marin County Parks, State Parks, NPS, Sonoma County Parks) in partnership with communities.	Education and outreach, CCC permit or federal consistency review.	Reduces erosion (problem for Bolinas Lagoon), creates habitat for estuary movement. May be perceived by the community as a loss of flood protection.	estuaries
4	Let go of pocket beaches that can't retreat, and do not intervene with management actions.	Those that can't be nourished or retreat.	Long-term	coastal erosion, sea level rise	CCC (LCP plan approval), Sanctuary, NPS	Public outreach will be required to explain inaction.		beaches/ dunes

5	For sediment-heavy estuaries, conduct instream and upstream restoration work to reduce sediment delivery and flash floods. Activities could include: - restore impaired and incised creeks - add large woody debris - reconnect creeks to floodplain - restore incised creeks by raising elevation to allow overflows/sediment deposition - dechannelize upstream segments - restore stream complexity - remove old road crossings and legacy roads, parking lots and other sediment sources - plant vegetation (e.g., drought/heat tolerant native species) - incentivize best land management practices that enhance soil health and decrease runoff and erosion (e.g., rotate land uses on agricultural upland properties, plant drought-tolerant natives, forest management) - build retention ponds/catchments that can be used for upland water management opportunities **For all activities listed, note that environmental conditions (e.g. storms, flooding, erosion, drought, SLR) can shift areas within estuaries between sediment-starved and sediment-heavy, so this action will need to be dynamic and respond to changing estuary conditions in the future.	Potential locations: areas within Pescadero Marsh, Bolinas Lagoon, San Gregorio, Tomales Bay, Drakes Estero.	Near-term	sediment supply, turbidity, land use change	Land owners (NRCS, Resource Conservation District, local cities and counties), SWRCB (TMDL info), Coastal Conservancy, upland managers, NPS for Drake's Estero.	Site-specific research to avoid invasive species introduction (vegetation management, impact assessments). Education and outreach will be needed to gain public buy-in, as footprint to restore the floodplain may be large, and may endanger houses and infrastructure. CCC permit or federal consistency review.	May alter habitat in upland areas. Could cause stream vs. estuary conflicts. Land owner/infrastructure challenges. Helps trap sediment/paces sediment release, enhancing estuary function. Enhances wetland filtering characteristics. Supports water infiltration and percolation. May benefit freshwater wetlands. Can help mitigate marine debris associated with storms.	estuaries
6	Encourage a climate-smart response to erosion events that smother the rocky intertidal by developing a diagnostic decision support tool so management agencies know how to respond to either 1) recover the habitat by removing material, 2) leave material and encourage surfgrass growth or 3) leave material and take the opportunity for creation of a new beach. Have the knowledge to take advantage of the new situation due to erosion events. Ideally would have some options with the ultimate goal of leveraging resources to provide the best response.	There are proximal (cliff failure) and more distant (debris flow from coastal watersheds) sources of sediment - to address more distant sources, focus on the largest coastal watersheds (Garcia, Gualala and Russian Rivers, Pescadero and Gazos Creeks) with soils, topography, etc. that are likeliest to yield the greatest amount of debris flows. To address more proximal causes (cliff failure), identify slide-prone areas and pursue cliff failure prevention (see strategy 16).	Near-term	coastal erosion, wave action, precipitation	USGS	Requires modeling done by USGS scientists.	For distance sources of sediment, this action also requires watershed management efforts to reduce devastating impacts of wildfires that remove extensive vegetation and result in debris flows that are more likely and larger.	rocky intertidal
7	Maintain streamflow to mitigate estuarine temperature increases and salinity changes. Activities to help maintain streamflow could include: - upland water management (e.g., implement best management practices) - dam releases - upland restoration - building and using water retention ponds (land owners draw water from ponds rather than stream)	Smaller estuaries and estuaries with closed bars. Potential location: Esteros de San Antonio and Americano.	Near-term (as needed)	temperature, mixing/stratification, precipitation, oxygen, pH, salinity	Regulatory agencies, CDFW, Resource Conservation District, NPS, land owners, local water supply and flood control agencies	Education/outreach: communicate how water use impacts estuary function and other habitats; Collaboration: can potentially coordinate with/build off regulation of instream flows. CCC permit or federal consistency review.	Consider the balance of human water supply (agriculture and residential) vs. ecosystem needs. Sediment supply/transport may increase; which may not benefit sediment-heavy estuaries. Moderating temperature may help mitigate algal blooms.	estuaries

Promote Education: strategies that address the need to educate the community

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
8	Develop a comprehensive education/outreach plan to address all of the 10 categories of strategy approaches in this report, including: partnerships with environmental ed orgs, schools and other public entities, social media and other communication strategies, interpretive signage and collaboration with other agencies and public entities to create a goal for climate literacy.	Region-wide	Near-term	all	Sanctuary			all
9	Enhance education programs (including marsh and tidepool education and interpretation programs) through training and guidance to communicate the implications of climate change and the exacerbating stressor of trampling and recreation on coastal habitats. Target existing programs (e.g. Duxbury and Fitzgerald Marine Reserves) and identify other highly-visited areas that need attention from volunteer docents. Docents should all have a common training core that includes climate change impacts and the exacerbating stressor of trampling and recreation on intertidal habitats, as well as tidepool etiquette and safety and the impact that impaired safety will have on natural resources. (i.e. boat groundings and the impact of emergency response). Strategies could include SLR visualizations and clean-ups.	Highly visited beaches, estuaries and tidepools.	Near-term	recreation/trampling	Sanctuary as the lead, in partnership with California Academy of Sciences, local cities and counties, NPS visitor center, Marine Mammal Center, Headlands Institute, State Parks, education programs and schools.	Existing docent programs. Funding and staff required to produce materials, curricula and trainings.	Effect on public access, public opinion. Opportunities for environmental education. Could link to Marin and San Mateo Counties YESS program and other school curricula	all

Protect and Restore Habitat: strategies that focus on protecting and restoring habitat or key ecosystem processes

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
10	Remove or modify structures that disrupt the delivery of sediment via long-shore sediment transport (jetties, breakwaters, storm and wastewater discharge pipes), and coastal and near-shore structures that contribute to erosion. Prioritize areas that are already impacted by these structures, and remove where possible. If the structure cannot be removed, then enable for managed retreat (for bluffs to feed the beach as sea level rises) and support beach nourishment to allow for beach expansion.	Potential locations: Pillar Point jetty which disrupts the delivery of sediment to surfer's beach in Half Moon Bay, areas along the Bolinas Lagoon shoreline where structures can be modified or living shorelines can be implemented, Oceanside Water Pollution Control Plant (including the westside transport box and Lake Merced Tunnel) and the Great Highway that impact Ocean Beach in San Francisco, structures that impact Fort Funston. Narrow road culvert at Schooner Bay, Drakes	Mid-term	coastal erosion, sediment supply and movement, wave action, wind, precipitation, overwater/underwater structures, sea level rise	Structure removal - Army Corps of Engineers, San Mateo County Harbor District, CCC, Sanctuary; Managed retreat - Caltrans, City of Half Moon Bay, CCC; Beach nourishment - Sanctuary, MBNMS, CCC, Army Corps of Engineers, SFPUC, Daly City, other local governments, Coastal Sediment Management Workgroup, Ocean Beach Master Plan, NPS.	Army Corps of Engineers staff, time and funds; CCC permit; political and local will. Living shorelines may need to be used to replace artificial structures and may require regulatory oversight through restoration - also may not be feasible on exposed outer coast beaches. Specific to the Pillar Point jetty: a feasibility study is near completion, and environmental impact review will be required regardless of the final action (though beach nourishment may only need an assessment). The MBNMS management plan may ned to be updated for longer term beach nourishment. A living shoreline to replace structure removal may require	The Pillar Point jetty is causing the erosion of surfer's beach, but the negative consequences of removing this structure may be too great for the community (in which case, managed retreat and beach nourishment should be implemented). This strategy protects and encourages expansion of sandy beach habitat, restores sediment influx, protects dune systems and infrastructure inland of beach, enhances recreational value, improves public access, prevents the impact of flooded infrastructure to natural system, reduces	beaches/ dunes

		Estero.				regulatory oversight through restoration.	further risk of erosion adjacent to the problem erosion areas, and allows coastal systems to respond naturally. This strategy may also result in changes to shoreline erosion, e.g. accelerate where shoreline is currently protected and decreased where currently accelerated.	
11	Create local and regional sediment management plans for full range of the sanctuary that are climate informed.	Exist: S. Monterey Bay, Santa Cruz, San Francisco (littoral cell internal draft is under review); still needed for: Marin, Sonoma, S. San Mateo County, San Francisco (central bay)	Immediate	coastal erosion, sediment supply and movement, wave action, wind	Army Corps of Engineers, Coastal Sediment Management Workgroup, State Parks, BCDC, local flood control districts, NMFS, CDFW, CCC, NPS, local cities and counties	Funding and staff		all
12	Restrict and direct human access on cliff base, face and top; including motorized transport.	Devil's slide (though this impact may be ameliorated by the tunnel), Jenner, Bolinas.	Immediate	coastal erosion, sea level rise, wave action, recreation, road/armoring	NPS, State Parks, BLM, local land trusts	Installation of fencing and signage; enforcement. Local governments can plan for restrictions to public access in their LCPs.CCC would need to approve signage and LCP updates. With consideration to Article 1, Section 25 of California Constitution that guarantees access to fishing grounds for citizens.		cliffs
13	Monitor dredge materials to be used for beach restoration or expansion for contaminants, make sure existing regulatory mechanisms control for contaminant exposure and take into account interaction with additional stresses form climate change (e.g. temperature, dilution concentrations, pH)	Region-wide	Immediate	dredging	SWRCB, RWQCB, EPA, Army Corps of Engineers	Requires sediment/sand testing/approval by RWQCBs. Report out at the San Francisco Bay Long Term Management Strategy (LTMS) meetings. POC: Brian Ross, EPA. CCC permit or federal consistency review.		beaches/ dunes
14	In the aftermath of a spill of oil or other contaminant, ensure that restoration of affected areas takes into account climate considerations (type of restoration, location of restoration, what should actually be restored based on climate envelope modeling to predict what species will likely become dominant). Oil spill restoration plans need to explicitly account for climate impacts on restoration of affected sites.		Near-term	pollution (oil spills)	CDFW OSPR, NOAA Restoration Office, NPS, USFWS, CCC	Collaboration of the responsible party with Federal, State of California, and tribal trustee agencies. Climate change modeling.	This recommendation is applicable to all habitats and affected areas.	all
15	Identify and purchase 1) cliff lands that are less likely to erode to provide enduring cliff habitat and public access, and 2) lands behind cliffs to allow for landward migration of cliff habitat.		Near-term	coastal erosion, sea level rise, land use change	State Parks, USGS, TNC, local land trusts, counties and cities, academic institutions	Funding, staff, research to identify cliffs less susceptible to erosion.		cliffs
16	Stabilize cliffs through revegetation (with native, climate appropriate species) and natural netting (e.g. jute, not chain-link fence). Design any hardening methods to take into account ecosystem needs (e.g. seabird nesting).	Places experiencing vegetation loss through social trails or other means (social trails are	Near-term	coastal erosion, sea level rise, wave action	California Conservation Corps, California Native Plant Society,	Appropriate species that will persist in the context of future change, permits.		cliffs

		paths not created by the land manager, but created by people walking repeatedly through a particular area to create a worn path)			Caltrans, land owners/managers (public and private)			
17	In restoration projects, use native, drought tolerant and heat resistant species or strains that fulfill ecological function of beach and dune processes.	Any location where restoration is proposed.	Near to mid-term	invasive and problematic species, air temperature	NPS, State Parks, land owners, National Audubon Society, California Conservation Corps, friends and stewards programs of the seashores and parks, Point Blue (use STRAW program's plant palette modified for dunes/beaches), CCC (through permit conditions or LCPs), local governments, Surfrider Foundation.	Create database of useful species to fill this niche (similar tool created for the Bayland Ecosystem Habitat Goals Update), source/supplier, staff and money, consider paleo/historic record to ID plants that thrived under previously similar conditions)		beaches/ dunes
18	Restore and/or create high marsh/upland transitional vegetation, wetland habitat, and deltas in areas that are flood-prone for multiple purposes: to accommodate landward marsh migration, to provide refuge habitat for marsh and upland species during high tide events, and to provide flood protection	Undeveloped upland areas adjacent to marshes and flood prone areas adjacent to estuaries, including Bolinas Lagoon north end and east side drainages.	Near-term: acquire habitat Long-term: restoration activity	temperature, sea level rise	Land owners in partnership with Land Acquisition Funds, National Audubon Society, NPS	Identify transitional wetland habitat using regional estuary modeling and inventories, and obtain land by coordinating with land acquisition action. CCC permit or federal consistency review.	Tradeoff with existing habitat: may require some modifications. May restrict grazing opportunities. Provides habitat for the threatened and endemic red-legged frog. Creates refuge habitat from temperature and high water events.	estuaries
19	Construct/augment coastal dunes. Remove/relocate shoreward constraints to dune movement and evolutions.	Many coastal locations (e.g. Stinson Beach, North and South beach of PRNS).	Mid to long-term	coastal erosion, wave action, sediment supply and movement	NPS, local governments	CCC permit or federal consistency review.	Impacts to recreation and visitor facilities through managed retreat and dune/wetland restoration. Shoreline recreation may be preserved but facilities may require relocation to offsite with shuttle to access beach. Would provide added protection to the town of Stinson Beach from SLR.	beaches/ dunes
20	Protect beaches in order to protect cliffs (see beach strategies: 4, 8-11, 13, 14, 17, 19, 22, 23, 25-27, 29, 32-39, 42, 44, 45, 49, 50, 54, 59, 60, 62, 66-71, 75, 76, 78).			coastal erosion, sea level rise, wave action				cliffs

Limit Human Disturbance: strategies that restrict or reduce access to sensitive habitats to limit disturbance and enhance resilience

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
21	Restrict human access to critical rocky intertidal areas. The type of access to rocky intertidal ecosystems that seemed	Critical habitat in the study region that	Near-term	recreation/trampling	CCC in partnership with Sanctuary,	CCC review of LCP updates or other plans.	Effect on public access, public opinion. Species	rocky intertidal

	appropriate in the 1960s may not be as appropriate now based on current knowledge of the increasing impact of people on these changing and likely more fragile ecosystems.	deserves protection from human impact: important larval source, highly visited, highly impacted.			CDFW, NPS, Coastal Conservancy, local governments in their LCP updates.		populations might continue to improve under additional protections against human disturbance.	
22	With the expectation that climate change impacts (such as those from storm activity and sea level rise) will reduce or cause major marine mammal haul-outs and seabird nesting sites to change, monitor and identify new locations of major marine mammal haul-outs and seabird nesting sites (see strategy 43) and provide protections for those locations. Reduce human disturbance, especially during times of heavy surf and inundation that will reduce availability of these habitats. Protect from major sources of disturbance from land, air and sea when appropriate, either as Special Closures, low overflight regulation zones or land-based closures. For example, NPS creates seasonal closure depending on the location of new elephant seal colonies and exposure to storm surf.	Historical areas - Pescadero Rocks, Bean Hollow, etc. Proritize the locations with the largest amount of disturbance to the largest breeding sites. Fitzgerald Marine Reserve already has this protection (cones are put out when mammals are present, and rangers are present), Pillar Point haulout has no protection. Spatially identify where these sites are and if there are new areas that will need protection due to SLR if used by marine mammals.	Near-term onward	wave action, recreation/trampling	CDFW - for vessel-based impacts, BLM, NPS, or USFWS for land-based impacts, Sanctuary or NPS for air-based and water-based impacts. Partners include: State Parks, NPS, county and city parks, Marine Mammal Center, Sanctuary (Beach Watch), MARINe, universities, Seabird Protection Network, CCC permit conditions for signage.	Public education (staffing for education and enforcement and resources like ropes and signs, interpretive materials). Provide spotting scopes for people to see mammals/seabirds up close. Better coordination amongst organizations and agencies to report new haulout areas, changing uses, etc. Landscape design of observation points, most protective to mammals and best vantage point.	SLR and storminess will flood haul out locations, especially during pupping season which overlaps with upwelling season – this may cause concentration of haul outs to fewer locations (erosion of north-facing beaches). Species conservation planning for marine mammals. Safety of boaters and pilots need to be considered.	all
23	Minimize access through dunes to protect dune stability.	Highly visited beaches that require access through dunes.	Near-term	coastal erosion, sea level rise, wave action, recreation	CCC, NPS, local cities and counties		LCP policies and permit conditions are potential ways to implement this management action	beaches/ dunes

Address Invasive Species: strategies that address the impact of invasive species on habitat resilience

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
24	Prevent non-native invasive species establishment (aquatic and terrestrial) in estuaries. Potential activities to prevent establishment include: - plant natives (e.g., in disturbed areas) - remove invasive species that are near/adjacent to estuaries that have the potential to invade (e.g., invasive tunicate, green crabs).	Region-wide	Near-term	invasive & other problematic species, sediment supply	Sanctuary in partnership with National Aquatic Invasive Species Group, SF Estuary Partnership, SF Estuary Institute, and other relevant estuary management agencies (CDFW, NPS, Marin County Parks).	Need an understanding of what species may invade the area, monitoring and maintenance, collaboration on education and outreach - work with local community and other management agencies to mitigate introductions and enhance participation. CCC approval of permits and LCP updates.	This action specifically prevents establishment (as compared to removing invasives that are already established)	estuaries
25	Update the definition of introduced/invasive/non-native aquatic and terrestrial species for Sanctuary management. An example for aquatic species may be that if it is a California Current species, it should be managed as a native, and expansions into the study area should be considered a migration or expansion.	Throughout study region.	Near-term	invasive & other problematic species, sediment supply	Sanctuary and relevant species management agencies	Specific definition might want to be revised by local experts - may want to re-word and change from California Current designated in this strategy and incorporate terrestrial species. Take into consideration the definition provided by the National		all

						Aquatic Nuisance Species Task Force and the Western Regional Panel.		
26	Enhance/establish the detection and monitoring of species changes (southern species moving north, northern species moving out and invasive species moving in) via a novel rapid assessment program. Something similar to Reef Check, partner with PISCO and MARINe (currently monitoring sites two times per year, needs to be more frequent and in more locations). Engage land managers (such as PRNS, CDFW, Sanctuary via LiMPETS) to leverage pre-existing efforts to detect and monitor. Create a uniformity of practice across the region.	Existing sampling sites (e.g. MARINe), especially those that are less disturbed, urban/more disturbed sites like Fitzgerald and Duxbury where volunteers and visitors can be engaged. Leverage citizen science networks and programs.	Near-term	invasive & other problematic species, sediment supply	MARINe, CDFW (base off of existing protocols for community assessments), Sanctuary should lead the effort if it is determined a novel program is warranted. NPS.	Monitoring programs, volunteer removal programs; outreach to corporations, schools, communities to volunteer. Protocols for identifying invasive species as well as the response - trigger criteria to launch a rapid response. Permit for collection of novel identified organisms. Funding will be needed. Build capacity through citizen science training (e.g. LiMPETS).	Check with Pete Raimondi on existing efforts (biodiversity plots) and consider altering this recommendation for better continuity and support.	all
27	Rapid response of non-native invasive species removal following detection to protect natural systems (e.g., control invasives via: manual removal, flooding, fire in transition zones; reestablish natives).	Region-wide with focus on National Parks (GGNRA, PRNS), State Parks, and private lands	Near-term	invasive & other problematic species	Sanctuary, NPS, State Parks, land owners, National Audubon Society, California Conservation Corps, friends and stewards programs of the seashores and parks	Build and use volunteer base for manual projects. Will require monitoring and maintenance. Education and outreach with community, visitors, management agencies. Funding. CCC approval of permits and LCP updates.	Rare plants and snowy plovers may benefit, but need to mitigate for increased depredation of plover chicks. Where European beachgrass and iceplant are pervasive, removal cannot be accomplished and sustained by volunteers or heavy equipment. May mitigate range expansions with warmer water. Helps restore sediment and hydrological movement. Volunteer engagement can enhance education/outreach efforts. Disturbance associated with removal could create habitat/opportunity for other invasives.	all
28	Remove non-native invasive plants (e.g. jubata grass) that undermine cliff integrity, and where appropriate, replant with natives or drought-/heat- tolerant species that support cliff structure.	Cliff habitat throughout study region.	Near-term	invasive & other problematic species	NPS, State Parks, CalTrans, local counties	Training, funds, CCC approval of permits and LCP updates.	Similar to actions for strategy 15 "Stabilize cliffs through revegetation"	cliffs

Promote Landward Migration: strategies that enhance the ability for habitat to migrate landward in response to sea level rise (SLR) and storms

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
29	To the extent practicable, remove/redesign roads in locations that act as barriers to natural expansion of habitats. Prioritize roads that are already impacted by high tides and start with those immediately. Always remove roads where possible; if not possible, redesign the road. Steps to accomlish this action in a changing climate include: 1) Identify areas that: A) are critical for estuary expansion and that have roads that impede estuary migration, and B) have roads vulnerable to sea level rise, flooding, other climate impacts 2) Develop Rapid Climate-Ready Response plans: develop plans that will allow for road removal/redesign in case of a disaster (e.g., road is wiped out in a flood) 3a) Post-disaster (flooding/road failure): implement the Rapid Climate-Ready Response plan to move/redesign road to a enhance future resilience 3b) If road is not impacted by climate change/extreme events, remove/redesign the road as available during standard maintenace schedule timeframes (i.e., when the opportunity arises to replace/redesign the road, take it)	Potential project locations: 1) Highway 1 along the east shore of Tomales Bay 2) North end of the Bolinas "Y" 3) Highway 1 at Pescadero Marsh 4) Sir Francis Drake Blvd near Drakes Estero (re-route or re-design) 5) Pescadero Creek Road 6) Highway 1 at Surfer's Beach in Half Moon Bay 7) Great Highway at Ocean Beach in San Francisco 8) Dillon Beach to Lawson's Landing	1) Long-term 2) Near-term (higher urgency) 3) Long-term 4) Near-term (higher urgency) 5) Near-term: assessment; Long-term: implementation 6) - 8) Mid to long-term	sea level rise, roads/armoring	"Local governments can plan for road relocation in their LCP updates. 1) A state agency should be identified to organize implementation in partnership with Caltrans, Sanctuary, CCC, County of Marin, and NPS. 2) Marin County Parks, County of Marin, Sanctuary, NPS 3) Caltrans, San Mateo County, CCC, State Parks, scientists 4) NPS and San Mateo County, CCC, USCG (need facility access), private ranching community, farm bureau 5) San Mateo County, NMFS, CDFW, Pescadero Fire Station (currently working on moving their flood-vulnerable facility) 6) Caltrans, City of Half Moon Bay, CCC 7) Caltrans, City of San Francisco, CCC 8) Caltrans, Marin County, CCC"	1) Do not anticipate the need for policy change in order to implement. Post-disaster planning might need to interface with local hazard mitigation plans. 2) Likely requires permit and environmental impact review; Needs project coordinator and adequate resources for assessments; Funding; Do not anticipate the need for policy change in order to implement. CCC approval of the plan, especially if elements are in the LCP update. 3) Need a place to move Hwy 1 5) Funding: partners can help leverage funding	Creates space and facilitates estuary movement in response to SLR, reducing vulnerability to flooding. Facilitates water and sediment movement throughout the estuary, improving hydrologic function. Improves connectivity between upland and lagoon habitats, with positive impacts on riparian and nursery habitat. Site specific benefits and consequences: 1) Provides more areas for eelgrass restoration in Tomales Bay. Reduces flood risks for human communities and infrastructure, enhancing long-term resilience. Also improves driver safety and traffic flow. Potential conflicts with tourism, transportation, infrastructure needs, etc. Road redesign may be the only feasible alternative since it is Highway 1. May need a causeway or reroute over the hills to the east at various locations. 2) Provides transitional habitat in an estuary where most of the edges are hardened. Road removal may cause loss of non-native and native species in habitat on other side of the road with unintended consequences; however, this area will eventually be inundated anyway. Transportation conflicts:	all

							local residents, tourists. Part of Marin County's sea level rise project - this action supports local efforts. 3) May improve dynamism of marsh morphology - Hwy 1 has low point near marsh, estuary bar is fixed under Hwy 1 bridge and can't move around, which likely affects marsh morphology. However, no records show the historical outlet so it is unknown how marsh morphology may change. Societal impacts of moving road: directing it toward a small town, tourism/recreation, safety routes, etc. Could negatively impact marsh depending on design. 4) This road (culvert/bridge) is at the pinch point at the head of Drakes Estero, and floods every winter. Would allow connectivity of habitats on each side of road, and prevent costly infrastructure maintenance. May be able to link to county program: San Mateo is identifying all roads vulnerable to SLR and affected by flooding. There are communities on each side of road; may affect access. 5) Road is at head of marsh and floods frequently because channel is filled with sediment. Could provide additional wetland habitat. County is moving fire station (Pescadero Fire Station Replacement Project) and looking at options for the road. There is an opportunity to leverage projects for multiple benefits.	

30	For roads that can't be raised/moved, or in conjunction with raising/moving roads, look for opportunities to create functional habitat (e.g., replace hard/grey infrastructure such as rip-rap with living shorelines and migration space)	Region-wide Potential location: install a horizontal levee at Bolinas Lagoon/Hwy 1	Bolinas Lagoon: Mid-term Region-wide: long-term, leverage opportunities when they exist	sea level rise, overwater/underwater structures, roads/armoring	Caltrans, Sanctuary, Army Corps of Engineers, RWQCB, NPS (GGNRA and PRNS), Sonoma County Parks, State Parks, land owners	Capitalize on natural destruction events, rebuild smarter. CalTrans would likely need policy adjustments (repair vs. rebuild); develop pre-planned response to road failures; revise planning horizons. CCC approval of a plan.	Creates functional habitat and space in areas that can't be moved/expanded. Short-term impacts to existing species/vegetation with habitat modification (e.g., may need to fill part of lagoon to create sloped transitional habitat).	estuaries
31	For locations identified as having coastal area available for developing new rocky intertidal habitat (see strategy 43), allow cliffs to erode to create new habitat. Discourage the creation of seawalls that would inhibit cliff erosion.	Create unfettered sea-to-land linkages for new habitat development. Where possible maintain the thread-like habitat continuity of rocky intertidal habitat north to south - avoid where possible large stretches of total inundation of rocky intertidal habitat. If design is possible, create new habitats that are less powerfully affected by storm damage, i.e., is there "wiggle room" to design new habitats that will be resilient to increasing storm surges.	Long-term	sea level rise	Sanctuary, NOAA Restoration Office, USGS, local cities and counties, land owners	Excellent marine geomorphologists, oceanographers, CCC federal consistency review.	May require efforts to clean up contamination sites, remove infrastructure at risk to provide adequate setbacks for development of new habitat - would link to efforts to control or manage coastal cliff erosion; intersects with intertidal species conservation strategies.	rocky intertidal
32	Explore legal and economic mechanisms to encourage coastal habitat protection in exchange for something analogous to an agricultural tax credit (e.g. coastal protection tax credit or transfer of development rights).		Near-term	coastal erosion, sea level rise, wave action, roads/armoring	CCC, local cities and counties, land owners	May need state legislature.	LCP policies and permit conditions are potential ways to implement this management action	beaches/ dunes
33	Exclude development in critical habitat areas and areas of potential habitat expansion through various policy changes. Exclusion language should be integrated into policies for retrofitting existing buildings, new construction, and rebuilding post-disaster. Add sea level rise conditions to general plans and local coastal plan updates.		Near-term	sea level rise, coastal erosion	CCC, Coastal Conservancy, local cities and counties, Center for Ocean Solutions (policy guidance), Georgetown Law Center, State Attorney General (legal guidance), UCLA Model Ordinance project (policy guidance)	Education and outreach: make changes amenable/understandable by the public. If needed, explore and investigate opportunities for how exclusion has been accomplished elsewhere (e.g., along the Napa River, other floodplain examples), and confer with groups with expertise in this realm (e.g., Nature Conservancy, Coastal Conservancy). Capitalize on large natural disasters - prevent vulnerable re-building that would negatively affect estuary migration.	Prevents construction/retrofits that can impede estuary migration. Prevents building construction that could fall into estuary habitat in the future. Public opinion may be hard to change. In long-term, benefits counties, cities, and homeowners: saves money by preventing the construction of structures vulnerable to SLR and flooding.	all

34	Prioritize locations, purchase or redesignate available land for inland movement of beach and dune habitat, using Open Space/Conservation Easements	Any site that is vulnerable to SLR and has potential to move inland.	Near to long-term	coastal erosion, sea level rise, wave action	CCC, local cities, counties and land trusts, Coastal Conservancy, land owners, State Parks, NPS, State Lands, BLM, TNC, Caltrans, FEMA (through Hazard Mitigation Plans), Army Corps of Engineers	Spatial prioritization, funding, knowledge of sediment circulation and supply	Might be in conflict with adjacent land management that is trying to abate SLR	beaches/dunes
35	Move or remove infrastructure that blocks or impedes habitat migration, or presents a potential risk of contamination to critical habitats, including utilities (e.g. power lines, sewer pipes), buildings, roads, or agriculture endeavors.	Places where lifetime of structure is ending or structure is creating a coastal hazard. Will likely be similar locations as road removal/redesign; all projects involving Hwy 1.	Near-term and long-term	sea level rise, overwater/underwater structures, coastal erosion	CCC, local cities, counties and land trusts, Local Coastal Programs, Coastal Conservancy, relevant utilities agencies and/or project lead of other barrier removal projects.	Planning for infrastructure relocation can be part of a local government's LCP update.	Deals with multiple obstructions at same time (co-benefits, leverage projects); facilitates estuary expansion. Availability of utility services	all
36	Work with counties to zone for protection of dunes and cliffs (setbacks, buffers, moratoria, elevate structures, designate areas of special biological interest for protection) to reflect changing coastal conditions		Mid-term	coastal erosion, sea level rise, wave action, roads/armoring	CCC, State Lands, local cities and counties		LCP policies and permit conditions are potential ways to implement this management action	beaches/ dunes
37	Consider the removal of seawalls (including rip rap) and make associated modifications to support retreat.	Where appropriate.	Mid to long-term	coastal erosion, sea level rise, roads/armoring	Caltrans, City of Half Moon Bay, CCC, Marin County, homeowner's associations (if applicable), NPS, local cities and counties.	Caltrans staff and time, funding (increase gas tax in San Mateo County), create sustainable development community with transit hub		beaches/ dunes
38	Assess the need to move or modify visitor facilities, pavement, and parking lots.	Visitor facilities (visitor centers, kiosks, bathrooms, signage, trails and parking lots)	Depends upon timing of impact	coastal erosion, sea level rise, roads/armoring	NPS, State Parks, CCC, local cities and counties	Funds, permits, staff time		beaches/ dunes

Invest in Science Needs: strategies that call for increased research to inform management

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
39	Develop a systematic research and science agenda to inform climate-smart adaptation.		Near-term		OST and NOAA.			all
40	Conduct regional inventory and modeling to identify how existing estuaries may change and identify potential areas for estuary expansion; use this information to set regional adaptation priorities. This effort includes: - completing current estuary inventory - identifying values of different estuaries (e.g., estuary harbors endangered species [or those that may become so], has valuable wilderness character, soundscapes, landscapes, lightscapes, pinniped breeding sites and haulouts, salmon	Study region	Immediate	sea level rise, precipitation, overwater/underwater structures, roads/armoring, coastal erosion	Sanctuary to convene a regional partnership of numerous land management agencies, scientists and funders. See "required resources" for a listing of partners that need to be involved.	Funding: variety of sources/joint venture (NOAA, NPS, Stanford Natural Capital Project, Universities/Academics, Federal Highways, foundations) Modeling: leverage current	Identifies how estuaries may change, and areas ripe for estuary expansion. Can be used to inform locations of all other adaptation actions, and helps prioritize sites for action. Short-term benefits: can identify where short-term	estuaries

	habitat, etc.] - identifying where future estuary habitat may move - better understanding how habitat types may change, and - better understanding and modeling system dynamics, and how they may change (e.g., how tidal prism may change) If possible: - Model entire region, utilizing current information/regional efforts and modeled future changes to identify net changes to estuaries - If not, model specific sites of management interest - If really limited, look only at the information we currently have (e.g., OCOF model) rather than conducting new modeling				.	data from existing regional efforts and combine with new modeling. Will need someone to lead data aggregation, plus someone to model (consider Point Blue and/or USGS) Data/models that should be used: - current estuary inventories from various management agencies/groups; combine these to make a regional inventory, and standardize/expand on detail collected for each estuary (e.g., key species, services provided, estuary values, etc.) - OCOF: use to identify what areas will be flooded; combine with salt water intrusion modeling, riverine flooding modeling (e.g., FEMA flood maps). Build in uncertainty by using max/worst case scenario projections - pollutant hotspots (critical to know if polluted area will be inundated; get data from EPA and regional/local environmental health agencies) - historic/archeological resources (NPS, State parks, counties) - sediment availability (identify if each estuary requires more/less sediment) - location of berms/levees/existing infrastructure/armoring - demonstration projects/lessons learned from regional projects (e.g., Muir Beach, Giacomini, South Bay Salt Ponds) Can create a decision matrix to go along with this process to facilitate future updates/repetitions.	measures are needed/feasible and identify opportunities to leverage resources with other groups and activities. Long-term benefits: guides prioritization of projects, can identify short-term actions within longer-term processes.	
41	Capitalize on natural extreme events to increase monitoring and knowledge of estuary processes and climate change impacts to inform adaptive management (e.g., monitor impacts of projected El Nino, study closed/open estuaries)	Study region	Near-term	precipitation, wave action, coastal erosion, turbidity, salinity, sea level rise, pH	Sanctuary, CDFW and OST. Relevant land owners (e.g. NPS) to lead monitoring on individual sites.	May require a Sanctuary staff member to lead data management and acquisition. Need rapid response monitoring teams ready to deploy (in case of extreme	Can help inform adaptive management and help mitigate negative impacts of extreme events in the future by better understanding natural	estuaries

						events). Need a standardized monitoring framework across sites; need to identify what Sanctuary wants to monitor for. Base locations on sites identified through monitoring and inventory action. Gather input from other groups (Bay Area Climate Change Consortium, CA LCC, agency partners). There are several estuaries that contain MPAs so it would be good to link the MPA monitoring efforts to other monitoring efforts for estuaries in the region.	processes. Builds knowledge to inform adaptive management. Can be used to increase education/outreach and public engagement.	
42	Determine the source of sediment for vulnerable beaches in order to improve sediment supply processes.	Wherever sediment patterns are vulnerable and uncertain	Near to mid-term	coastal erosion, sediment supply and movement, wave action, wind	Sanctuary, Coastal Conservancy (for funding), academic institutions, NPS, USGS, Army Corps of Engineers, Coastal Sediment Management Workgroup	Researchers, funding	Implications for estuary management and cliff erosion. Possible counteracting sources (e.g. cliff erosion and long-shore current counteract).	beaches/ dunes
43	Identify future viable locations for rocky intertidal habitat migration inland either through modeling or known information (how do rocky intertidal areas form, and would there be available rock inland for habitat migration? Is there rock under the cliff bluffs or under the sand?). Identify future viable locations for seabird and marine mammal breeding sites and haul-outs.	TBD through modeling analyses and site analyses. Some modeling has been done at PRNS for elephant seals.	Long-term	sea level rise	USGS, universities.	Modeling, interagency collaboration of Federal, State, County, and municipal governments; regional planning - perhaps along the lines of planning zones used in Area Contingency Plans; Army Corps of Engineers might have very useful expertise	This strategy informs the implementation of strategies 22 and 31. This activity intersects with intertidal species conservation strategies.	rocky intertidal

Protect Species: strategies that directly protect species rather than habitats

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
44	Designate, expand, and increase enforcement of resource management areas to enhance and support special protections for target species in the context of climate change.	Study region	Near-term	coastal erosion, sea level rise, temperature, precipitation	CDFW, NOAA OLE, BLM, USFWS, NPS, State Parks, relevant land managers	California Coastal Commission permitting		beaches/ dunes

Manage Water Quality: strategies that improve water quality to enhance habitat resilience

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
45	Improve storm water management by reducing combined sewer overflow events.	Ocean Beach, Fort Funston, Pacifica, other locations with combined sewer overflow	Near-term	precipitation, coastal erosion	SFPUC or Public Works, CCC for review of permit or LCP updates.	Funding for infrastructure improvements and/or replacements	Improves water quality	beaches/ dunes

46	Capture and redirect storm water away from cliff face into better infiltration systems to reduce erosion and avoid landslides.		Near-term	pollution, precipitation	Local cities and counties, SWRCB, CCC	Hydrology information, funding for contracts to regrade/swales/etc, local permits		cliffs
47	To prevent algal blooms, Regional Water Quality Control Boards that manage TMDLs for nutrients should consider stricter prohibitions for effluent flows of excessive fertilizer to address stressors of excessive nutrients at low flow times into the ocean, a situation likely to get worse with climate change. See publication: http://pubs.acs.org/doi/pdf/10.1021/acs.est.5b00909.	San Francisco Bay (Napa and Sonoma rivers have TMDLs for nutrients which are now under consideration for delisting), Walker Creek and Tomales Bay (mercury and pathogens only, not nutrients), and Russian (phosphorus in the Laguna de Santa Rosa) rivers all have water quality impairments for nutrients. TMDLs are under development for Fitzgerald Marine Reserve (for bacteria) and for Pescadero Marsh/Butano Creek (sediment).	Near-term (higher urgency)	pollution, oxygen, stratification	RWQCB, SWRCB, California Farm Bureau, Natural Resources Conservation Service.	Local Resource Conservation Districts. Sanctuary to help track water quality changes through monitoring (ACCESS cruises) with partners (Point Blue).	Decrease the possibility of negative impacts due to blooms smothering the intertidal (macro) and changing water quality (micro). Planning to reduce debris flows from storms, efforts to reduce mercury input into coastal waters	rocky intertidal
48	Take a watershed approach for rocky intertidal areas near estuary mouths, streams, etc. to limit sediment and improve water quality entering from the watershed: 1) Watershed managers and regional water quality control boards should enforce TMDLs with forestry operations, municipalities, agriculture, etc. to limit sediment coming down into the intertidal area. 2) Incorporate climate considerations into formulation of TMDLs in specific locations (see site specific category) to respond to predicted climate change impacts on outflows of sediment, toxins and nutrients.	Potential project locations: 1) Garcia River estuary next to Point Arena intertidal reefs. Farmland and forestry operations upstream. 2) Gualala River next to Gualala Point. Logging and land recently purchased as conservation lands. 3) Russian River with rocky intertidal both north and south of estuary mouth. Mercury-rich sediments from mines upstream. Forthcoming inclusion of Lake Mendocino and Lake Sonoma in the Statewide Reservoir Mercury TMDL. 4) Pescadero Creek with rocky intertidal area just south of estuary. 5) Gazos Creek with Ano Nuevo just south. Timber logging upstream.	Near-term	coastal erosion, precipitation, land use change	For all potential projects: SWRCB and RWQCBs, local cities and counties, relevant forestry, farming, mining, logging operations upstream. Additional: 2) Gualala River Watershed Council, Friends of Gualala River 3) Russian River Watershed Association, Russian River Watershed Protection Committee	Collaboration among rocky intertidal managers (BLM, CDFW, State Parks, Sanctuary) and RWQCBs. Need to secure immobilization of pollutants as the disturbance regimes along coastlines, coastal rivers and streams, and uplands intensify. CCC review of plans.	Negative impact on sediment-starved estuaries. Note that San Francisco Bay and Tomales Bay have TMDLs for mercury.	rocky intertidal

49	Improve storm water management by creating bioswales and other urban run-off reduction tools (e.g. permeable pavement, street trees/catchment/storage).	Pacifica/Linda Mar Beach, San Francisco, Half Moon Bay and other San Mateo County Unincorporated Areas, all highway locations in the five county area	Near to mid-term	precipitation, coastal erosion	Local cities and counties, Friends of the Urban Forest, California Conservation Corps, The Arbor Day Foundation, CCC (in permit conditions or LCPs), ASBS funding	Wetland vegetation, saplings, staff or volunteers	Improves water quality, and reduces beach erosion	beaches/ dunes
50	Improve storm water management by reducing agricultural (croplands and livestock) run-off (buffer strips).	San Mateo County, Lawson's Landing, Sonoma County, Tomales Bay	Near to mid-term	precipitation, sediment supply and movement	Resource Conservation Districts, SWRCB, CCC (in permit conditions or LCPs)	Grants and conservation easements for private landowners	Improves water quality	beaches/ dunes

Additional Strategies (lower priority)

Alleviate Climate Impacts: strategies that directly reduce the impact of climate stressors

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
51	Restore and enhance lower intertidal mussel beds and algae, including sea palms (a species identified as vulnerable), to buffer from storm activity by enhancing structural roughness (physical/structural resistance) to lessen impacts of storms on intertidal zones.	Consider the evolving (new) subtidal and intertidal zones	Near-term onward	wave action	Sanctuary and landowners (NPS, CDFW, State Parks, State Lands Commission) in partnership with NGOs to get funding	Marine and coastal habitat restoration ecologists; monitoring to address efficacy. CCC permit or federal consistency review.	Facilitates species colonization and recovery from disturbance due to an increase in ocean wave energy that may destabilize and transform intertidal habitats.	rocky intertidal
52	Restore subtidal kelp forests to attenuate waves and buffer from enhanced storm activity.	Select locations that do not currently have kelp but have appropriate conditions for kelp settlement and growth (good light and water quality, little turbidity).	Near-term onward	wave action, coastal erosion	Sanctuary in partnership with NPS, Bodega Marine Lab and UCSC. NGOs and Coastal Conservancy for funding.	Monitoring to address efficacy. CCC permit or federal consistency review.	Reduces ocean wave energy in subtidal habitats as a further step to reduce energy impacts in the intertidal zone - to modulate the intensity, frequency, and duration of storm impacts. Reduces sediment and turbidity in the intertidal. Creates habitat for subtidal systems that supports objectives for rocky intertidal ecosystems. Need to balance with any commercial programs for kelp collection. Learn from Southern California efforts. Seek funding for a research project at Bodega Marine Lab.	rocky intertidal
53	Restore and enhance surfgrass *(Phyllospadix)* and algal species to act as aqueous canopies and provide shading to reduce temperatures and reduce evaporation in tide pools.	Prioritize intertidal reefs that are most vulnerable to prolonged exposure and heat stress. Potential locations include: Tomales Bay headwaters, Point Reyes Headland, Palomarin, Pescadero State Beach, San Gregorio State Beach, Fitzgerald Marine Reserve, Año Nuevo State Park, Pigeon Point, and Pillar Point for *Phyllospadix scouleri*, and Moss Beach for *P. torreyi* (see calflora.org for more information on species distributions).	Long-term	air temperature, sea surface temperature, salinity	Sanctuary in partnership with NMFS, Coastal Conservancy, CDFW, NPS, other agencies that manage marine resources, and NGOs to assist with funding	CCC permit or federal consistency review.	Additional benefit is carbon sequestration and local mitigation of the impacts of ocean acidification provided by surfgrass restoration.	rocky intertidal

54	Diminish heat stress by testing the efficacy of shade delivery systems (including nest umbrellas/boxes/tents and revegetation) or encouraging animals to nest in more protected areas.	Farallon Islands, critical nesting sites	Near-term	temperature, precipitation	USFWS, Point Blue, State Parks, CDFW, NMFS, NPS, relevant coastal land owners and managers	Determine need for seal pup thermal protection; California Coastal Commission permitting	Make out of solar fabric for ancillary power production (e.g. fans if needed). Create possible user experience/education tie-in, such as renting similar umbrellas to beach users.	all

Manage Dynamic Conditions: strategies that are responsive and adaptive to changing conditions

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
55	Manage the bar: - create a breach if estuary closes and conditions are detrimental to estuarine species or resources of interest - actively close the bar if estuary is open and conditions are detrimental to estuarine species or resources of interest	Site specific: will largely depend on estuary condition (e.g., breach may be required in case of restricted passage or poor water quality; closure may be required to capture necessary freshwater outflow or to protect from marine pollutants) Potential areas for breach: Bolinas Lagoon (although natural closure may be unlikely with sea level rise), Pescadero Marsh, Russian River, Muir Beach, San Gregorio, Tunitas Creek, Pomponio, Rodeo Lagoon, Gazos Creek, steelhead or salmon bearing streams that have restricted passage Potential areas for closure: Nursery grounds (e.g., Russian River - salmon), or in case of pollutants (e.g., done at Rodeo Lagoon in the past to protect from oil spill)	As conditions require.	precipitation, oxygen, pH, water temperature, salinity, turbidity, currents/mixing/stratification, temperature	Partnership with land owners, County (equipment/staff), Sanctuary, regulatory agencies, Coastal Commission, community support. Lead agency may be different if species of concern isn't a key commercial or T/E species, or depending on who wants the action done	Need to first accomplish in the near-term the policy/permitting framework (programmatic permits required for each system; must be very site-specific and lay groundwork for approval ahead of time) and a better understanding of individual system dynamics to identify when this management action would be beneficial/harmful. Will also require agency coordination (esp. related to breach timing). Funding needed to monitor impacts and cover permit costs.	Creating a breach may ameliorate stagnant water impacts, poor water quality, limited passage (anadromous fish [juveniles/adults], recreation, other biota) and promote hydrologic and sediment transport. May cause earlier opening in the future, and could affect marsh accretion and water chemistry (methyl mercury production). May provide positive education opportunity around resource values, and may benefit certain human communities that believe the septic system doesn't function when estuary is closed. May also help prevent algal blooms by moderating temperature. Closing the bar may capture freshwater and protect/maintain related freshwater habitats, including nursery grounds, when runoff is pulsed. May reduce recreational use/access and/or become stagnant and smelly. Could cause loss of sediment (depending on how it's done), shorebird foraging habitat/subtidal habitat, haulouts, cordgrass, and mud organisms (due to	estuaries

							anaerobic conditions).	
56	Reconsider sediment requirements and stream management mandates to ensure sustainable sediment delivery to estuaries. Activities could include: - conduct sediment study for each estuary site to determine if estuary is sediment-starved or keeping pace with sea level rise - recommend that sediment management plans be climate-informed	Region-wide, but prioritize sediment-starved areas within estuaries. Potential location: Tomales Bay	Near-term	sediment supply, coastal erosion, sea level rise	Army Corps of Engineers in partnership with Coastal Sediment Management Working Group, CA State Sediment Master Plan, other sediment management and planning efforts. Coordination with SWRCBs for TMDLs. NPS.	Expand existing groups/efforts to look at estuaries. Utilize existing monitoring data from NPS, USGS, and gather high resolution data for sites of interest.	Could benefit beach systems. Enhancing sediment delivery may not be possible if streams harbor sensitive species (e.g., salmonids).	estuaries

Protect and Restore Habitat: strategies that focus on protecting and restoring habitat or key ecosystem processes

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
57	Protect and promote eelgrass growth; protect existing beds and restore areas that have been adversely affected by human activities, such as aquaculture operations, moorings or other infrastructure.	Potential locations: Tomales Bay, Esteros de San Antonio and Americano, Bolinas Lagoon, Drakes Estero.	Immediate	pH, overwater/underwater structures, temperature	CDFW, California Fish and Game Commission, State Lands, Sanctuary, NPS	Requires funding, enforcement to protect current beds from degradation and to protect restored areas, and education and outreach. CCC permit or federal consistency review.	Enhances nursery grounds. May help regional carbon sequestration. Economic benefits (oyster farming). Need to work with oyster companies to reduce light blockage and other damage from anchors, racks, floats.	estuaries
58	Remove overgrowth of macroalgae (ulva blooms) from rocky intertidal habitat as they occur.	Areas impacted by major overgrowth.	Immediate	pollution, oxygen	Sanctuary	Permitting	Potential impacts to the intertidal area due to trampling and harvest - needs to be done in a way that does not impact resources (consider only free-floating harvest by vessel). Separate approach (Water Quality Management strategy) focuses on reducing pollutants from estuaries and run-off.	rocky intertidal
59	Beach nourishment	Potential locations: Ocean Beach: middle and southern reaches, Stinson Beach, Inverness, East Shore, Dillon Beach, Lawson's Landing, Salmon Creek, Jenner, Half Moon Bay, Surfer's Beach, pocket beaches on Farallon Islands, Point Arena, Manchester State Park, Gualala Point	Near to mid-term	coastal erosion, sediment supply and movement, wave action, wind	City of San Francisco, Army Corps of Engineers, NPS, State Parks, USFWS, SPUR, USGS, SFPUC, CCC, Sanctuary, local harbor districts, cities, and counties, Coastal Sediment Management Workgroup	Sand, money, staff, federal permit, CCC permit or federal consistency review.	Implications for beach and benthic invertebrates. Forestalls beach hardening to maintain habitat. Potential to establish dune vegetation. Carbon emissions from implementation may be significant. Impact to surfing uncertain. Consider where sediment source is blocked by dam	beaches/ dunes

		Regional Park, other locations as identified in the draft San Francisco Regional Sediment Management Plan					or otherwise. Apply for both human and wildlife access. Preserves/prolongs beach habitat values, as well as public recreation and access.	
60	Install beach sediment traps (add good jetties, giant fine mesh nets, sand flume cells) to accumulate sediment where needed.	Cliff-backed beaches, pocket beaches, high erosion beaches.	Long-term or emergency measure	coastal erosion, sediment supply and movement, wave action, wind	Caltrans, Army Corps of Engineers, CCC, State Lands, Sanctuary, landowners/managers	Spatial assessment, feasibility and efficacy studies, permits. Take into account wildlife impacts.	Wave energy generation. Artificial habitat created on structures.	beaches/ dunes
61	Restrict livestock access to cliff top, including rotational grazing plans.	Hwy 1 north of Jenner; Sonoma and Marin Counties	Immediate	coastal erosion, sea level rise, land use change	NPS, TNC, local counties and land trusts, private land owners	Agreement with ranchers, resource conservation districts		cliffs
62	Evaluate and remove or modify barriers to riverine flow and sediment supply (dams, bridges, culverts, and flood-control gates) to allow for greater sediment transport to beaches and estuaries.	Throughout region, including dams on rivers draining to SF Bay, water district dams - Lagunitas Creek, Russian River, Gualala, Walker Creek. Focus upstream of sediment-starved estuaries and beaches.	Near to long-term	sediment supply and movement, precipitation, overwater/underwater structures, sea level rise, coastal erosion	Army Corps of Engineers, BLM, Resource Conservation District, Bureau of Reclamation, DWR, Coastal Commission, watershed organizations and water districts, partnerships with dam managers.	Funding, support from upstream/downstream communities, will require impact studies	Restores natural sediment regimes to help with accretion; helps hydrology and water movement; promotes healthy function; improves beach access; possible trade-off in current discharge rates; possible tie-in to salmon access. Potential negative impacts of dam removal: shifts in open water habitat, water supply and storage, hydrological regime (increased water and uncontrolled flooding), contaminant loads, upstream habitat, recreational access, change in timing of availability of water.	beaches/ dunes and estuaries
63	Engineer marshlands to enhance water flow and balance sediment transport. Activities could include sinuous channelization.	Apply to restoration projects; flood-prone estuaries; sediment-heavy estuaries; archaeological sites/past development sites (i.e., where erosion may be an issue)	Long-term	sediment supply, sea level rise, oxygen, temperature	Local counties, ranches, Resource Conservation District, NMFS (salmonids), CDFW (fairy shrimp)	Planning, coordination, and knowledge: channelization has been done at Giacomini - could use similar resources. CCC permit or federal consistency review.	Pollutant mobilization (e.g., mercury - Walker Creek), short-term impacts to existing species/vegetation with habitat modification. May moderate temperature which may help mitigate algal blooms.	estuaries
64	If a barrier is required to protect human infrastructure, determine the most beneficial material to use and the best design to encourage rocky intertidal species to colonize and/or migrate landward. This is not a recommendation to create new barriers, and should only be implemented where totally necessary, or the barrier is already in place and opportunities exist to refashion the barrier / infrastructure in a way that promotes a simultaneous habitat use with the barrier.	Only in locations where a barrier is necessary.	Long-term	armoring, coastal erosion, wave action, sea level rise	CCC and local counties and cities, academic institutions, Army Corps of Engineers	Resources to identify best design to use for armoring, working with CCC to allow for different armoring materials and designs. Working with local universities on engineering.	Potential interactions with nearby beaches with sediment movement based on oceanographic conditions. The littoral zone – doing work on sediment movement in San Mateo/SC counties.	rocky intertidal

65	Protect cliffs from erosion to protect rocky intertidal habitat from smothering (see cliff protection strategies: 8, 9, 11, 12, 14-16, 20, 22, 25-29, 33, 35, 39, 46, 54, 61,69).							rocky intertidal

Limit Human Disturbance: strategies that restrict or reduce access to sensitive habitats to limit disturbance and enhance resilience

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
66	Prepare for increased beach use in the event that climate change results in dryer, sunnier weather, including managing traffic, litter, visitor services, etc.	throughout region	Near-term	recreation, temperature, coastal erosion, sea level rise	State Parks, NPS, State and County Departments of Public Health, volunteer groups (such as Save Our Shores, Pacifica Beach Coalition)	Organize volunteers for beach clean-ups, funding.	Build new infrastructure (e.g. bathrooms) to accommodate more visitors. Increase schedule of litter clean up.	beaches/ dunes
67	Manage pet beach experience/access (leashes, locations)	Known haul out, nesting and restoration sites, shorebird wintering sites	Near-term	recreation, temperature, coastal erosion	State Parks, NPS, BLM, County Parks, Municipal Parks	Increased signage and enforcement, CCC permit or federal consistency review.		beaches/ dunes
68	Manage or control density and distribution of beach users if beaches become too impacted by high visitation, while respecting the public's right to access the coast.	Highly visited beaches.	Near-term	recreation, temperature, coastal erosion, sea level rise	State Parks, NPS, BLM, County Parks, Municipal Parks, CCC (permit conditions or LCPs)	Funding, staffing, consider reservation system (see Point Lobos example), signage, outreach, enforcement, CCC permit or federal consistency review.	Seasonal closures may be more effective and efficient.	beaches/ dunes

Promote Landward Migration: strategies that enhance the ability for habitat to migrate landward in response to sea level rise (SLR) and storms

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
69	Provide incentives for people to voluntarily relocate in areas that were, or could be, sensitive habitat, or where development reduces habitat resilience: - Incentivize managed retreat if space is available - Initiate and practice land trading (e.g., trade less valuable park land for private land that is vulnerable to flooding and that currently blocks habitat migration) - Purchase land, when possible, to facilitate habitat migration	Areas where habitats are impaired and can't migrate, infrastructure is projected to be inundated anyway, and/or areas where barrier removal would improve habitat function or resilience.	Near-term: land acquisition Long-term: land trading, but start laying policy foundation now	sea level rise, coastal erosion, precipitation	Agencies that own or abut land, land owners, NPS, Army Corps of Engineers, local cities, counties and land trusts, Resource Conservation Districts	Funding via joint venture with many groups, maybe insurance companies. Will need tradeable land. Policy changes may be required (e.g., congressional change to allow trading of NPS lands). Education and outreach will be critical to gain public support; utilize regional modeling to show current land owners why moving is the smartest financial decision. If needed, explore and investigate opportunities for how this has been accomplished elsewhere and confer with groups with expertise in this realm. Golden Gate and Point Reyes (NPS) have already acquired estuary-adjacent parcels that have come up for sale (NPS has a lands acquisition program).	Removes structures that are going to be destroyed by flooding and/or structures that could fall into the Sanctuary. Provides habitat/room for estuaries to expand. Land trading may affect other terrestrial habitats (i.e., may allow for construction in new areas). Can combine with removing non-functional infrastructure (e.g., eliminate old berms and flood levees). Will likely face public opposition, but there are long-term benefits to human community: structures will eventually be destroyed by flooding, cheaper to move the infrastructure now.	all

70	Create a Transfer of Development Rights program in areas needing protection to reflect changing coastal conditions. In hazard areas or sensitive habitat areas that will be threatened by SLR over time, transfer development rights from vacant lots not suitable for development to other locations in the jurisdiction		Mid-term	coastal erosion, sea level rise, wave action	CCC, local cities and counties		LCP policies and permit conditions are potential ways to implement this management action	beaches/ dunes
71	Work with County general plans and coastal zone LCPs to consider development in anticipation of sea level rise.		Mid to long-term	coastal erosion, sea level rise, wave action, roads/armoring	CCC, local cities and counties	Could be accomplished with a state level statute		beaches/ dunes

Invest in Science Needs: strategies that call for increased research to inform management

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
72	Promote estuarine research to enhance eelgrass restoration efforts. Major research questions may include: - Eelgrass distribution: why is there no eelgrass in Bolinas and Pescadero? - Do salinity and turbidity affect eelgrass establishment and persistence?	Study region	Near-term	salinity, turbidity, pH, temperature	Sanctuary, academic institutions, oyster companies	Knowledge: look at case studies from San Diego area, east coast and Gulf coast, San Francisco Bay research, Drakes Estero research to document recovery by CDFW.	Helps inform eelgrass restoration efforts, which enhances estuary habitat, and may enhance regional carbon sequestration efforts. Economic benefits (oyster farming)	estuaries
73	Pursue and encourage research in OA-mitigation methods including the restoration and expansion of photosynthesizers (kelp, surfgrass) to locally mitigate the impacts of OA and sequester carbon). Sanctuary should seek partnerships with technical experts who wish to establish experimental treatment plots to test these mitigation techniques.	Establish experimental treatment plots that test the effectiveness of management measures based on scientific expertise	Near-term	pH	Sanctuary (support from CDFW, State Parks, NPS, BLM, local counties)	Sea Grant funding to research institutions, CCC approval and permits for test plots.	Strategy would likely stabilize species populations, and facilitate habitat creation for new assemblages of intertidal communities whose species are shifting their range as the result of climate change impacts.	rocky intertidal
74	Better understand climate impacts on larval dispersal to ensure that larval source locations are effectively protected within the MPA system and are able to reach various intertidal areas (inside and outside MPAs). Investigate larval dispersal of key species and how this relates to distances among MPAs. Also consider important areas that are not currently designated MPAs.	All MPAs in the study region and additional important rocky intertidal areas.	Near-term	currents/mixing	CDFW in partnership with researchers and OST.		Strategy would address decreased larval density due to increased turbulence of the water column (reduced survival) and increased offshore advection of larvae due to increased wind.	rocky intertidal

Protect Species: strategies that directly protect species rather than habitats

Ref #	Strategic Management Action	Spatial or site-specific details	Time-frame	Stressor(s) addressed	Key Partners	Required Resources	Notes	Habitat
75	Augment haul-out and nesting sites: floating haul outs, larger buoys, artificial offshore floating structures	Study region	Near to mid-term	coastal erosion, sea level rise	USFWS, NMFS, USCG, Sanctuary, NPS, State Parks, County Parks, CDFW, Boating and Waterways, Marine Mammal Center	California Coastal Commission permitting	Possible benefit - wave energy generation	beaches/ dunes

76	Support animal rescue and rehabilitation services.	Study region	Near-term	temperature, precipitation	Marine Mammal Center, NOAA MMPA , USFWS, USGS Western Ecological Research Center, MBARI, Point Blue, NPS.			beaches/ dunes
77	Incorporate climate change into fisheries management to address the impact of ocean acidification and climate stressors. Exact strategy would depend on how specific species are being impacted. Monitoring to track impacts and effectiveness of regulations will be needed.	Extend protection from harvest in the rocky intertidal to the mean high-tide line next to marine protected areas (state and fed) where feasible. Maintain seamless consistency in degree of protection/mgmt.	Near-term – actions already in place	pH, harvest	NMFS, CDFW, State Parks and County Parks, NPS.	Increased monitoring of harvested OA-sensitive species (mussels, abalone) with triggers or thresholds. Increased funds for CDFW wardens and Parks Rangers to patrol and check permits. Requires public education and cooperation – outreach and stewardship. Monitoring teams to detect effectiveness of regulations (tie-in with Ocean Science and Marine Reserve System monitoring)	Would provide greater benefit to rocky intertidal community by increasing/maintaining biomass of species and surface roughness (maintaining functional habitat).	rocky intertidal

Manage Water Quality: strategies that improve water quality to enhance habitat resilience

Ref #	**Strategic Management Action**	**Spatial or site-specific details**	**Time-frame**	**Stressor(s) addressed**	**Key Partners**	**Required Resources**	**Notes**	**Habitat**
78	Manage for flash flood and high flow events that might adversely affect existing and new vegetation by increasing absorption and decreasing runoff. Strategies may include: improve culverts, pumps, tide gates, bridges, stream management, increased use of permeable pavement and increased absorption opportunity, all communities require rain barrels.	Locations prone to flooding: Stinson Beach, Muir Beach, Lagunitas Creek, Hwy 1 in many locations	Near to mid-term	precipitation, coastal erosion	Caltrans, local cities and counties, Flood control districts, FEMA, California Office of Emergency Services, CCC (in permit conditions or LCPs), NPS	flood maps, money, community will	Sediment deposition, salmon habitat impacts from flood control actions.	beaches/ dunes

References

Gregg, R.M., L.J. Hansen, K.M. Feifel, J.L. Hitt, J.M. Kershner, A. Score, and J.R. Hoffman. 2011. The State of Marine and Coastal Adaptation in North America: A Synthesis of Emerging Ideas. EcoAdapt, Bainbridge Island, WA.

Hutto, S.V., K.D. Higgason, J.M. Kershner, W.A. Reynier, D.S. Gregg. 2015. Climate Change Vulnerability Assessment for the North-central California Coast and Ocean. Marine Sanctuaries Conservation Series ONMS-15-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 473 pp.

Moore, S.S., N.E. Seavy, and M. Gerhart. 2013. Scenario planning for climate change adaptation: A guidance for resource managers. Point Blue Conservation Science and California Coastal Conservancy.

Appendix A. Climate Scenario Summaries

The climate scenario summaries are based on best professional judgement and assessment of potential future conditions in the region. These summaries were developed as a tool for working group members in this planning process and are not meant to advise or guide future planning efforts.

Scenario Summary

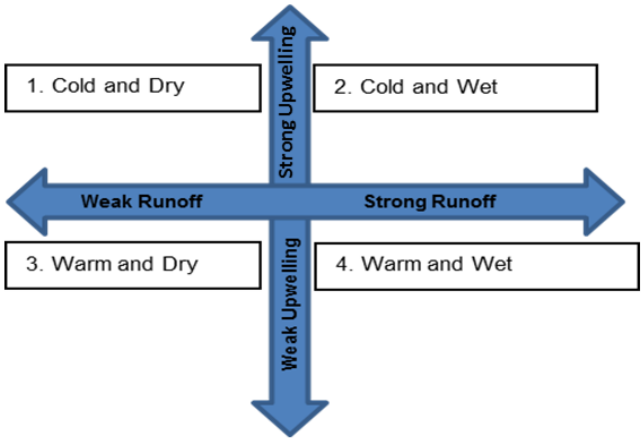
Working with the assumption that sea level is rising (as there is no realistic scenario of falling sea level) and that oceans are becoming more acidic, this leads to a set of four scenarios based on whether upwelling increases or decreases and whether freshwater runoff from land increases or decreases. There is high uncertainty about changes in the upwelling and runoff scenarios and also these two seasonal phenomena are foundational factors accounting for the character and changes in California marine environments. The future may bring colder or warmer spring/summer/fall waters depending on upwelling and it may bring either wetter or drier winters.

Scenario Drivers

Runoff: Runoff is a general term referring to the impacts of flooding that occur with storms of greater magnitude and/or higher frequency than occur currently. With increasing precipitation we expect to see greater runoff from rivers and storm drains into coastal waters. Additionally, we expect higher waves and southerly winds that are consistent with high precipitation storms that could increase coastal flooding.

Upwelling: Changes in the frequency or intensity of north winds are expected to have impacts on upwelling patterns. North winds drive upwelling of cold enriched waters and thus control exposure to low pH, low dissolved oxygen (DO) and high nitrate concentration; also rough spring/summer seas, cold air temperatures, and fog are associated with upwelling.

Sea level: Increases in sea level are expected to change the extent and distribution of intertidal habitats. Sea level rise (SLR) combines with waves and winds to increase coastal flooding and erosion.



Ocean acidification (OA): Changes in carbon dioxide levels in the ocean from atmospheric sources are expected to lead to changes in the acidification of the ocean waters. Changes in ocean pH may be regionally/locally mitigated

or enhanced by changes in upwelling, runoff and organic/nutrient loading of runoff.

Upwelling/ sea level rise interaction:
Increased upwelling (north winds) and decreased winter storms (south winds) both result in lower sea levels. North winds lower sea level by up to 20-30cm and absence of south winds is absence of setup by 30-50cm; therefore, SLR is mitigated in both seasons. Decreased upwelling results in higher sea levels in spring/summer and increased south winds results in higher sea levels in winter, so SLR is enhanced in both seasons. In both cases, during big wave events, the sea level can be held up by another 30cm, which would lead to more inundation. Greatest impacts will be observed at spring tide, but tides should change negligibly with climate change.

Detailed Scenario Descriptions

1) Cold and Dry (weaker runoff with drier winters, stronger upwelling with colder summers)

Scenario narrative
Strong north winds in spring and summer drive upwelling, with high nutrient flux to the euphotic zone supporting productive bays and coastal waters – with increased upwelling, phytoplankton blooms will occur farther offshore in open coastal waters due to offshore transport, leaving nearshore systems less productive with impacts on birds, whales and out-migrating salmon. But waters that are entrained and retained in bays will fuel enhanced productivity in sheltered waters and fixed kelp forests will do better with more nutrients and more light (no shading by phytoplankton), supporting the communities that feed in these habitats. Stronger upwelling will bring low oxygen/high CO_2 water from greater depths, which will enhance the OA trend, thus impacting many bivalve larvae/juveniles, larval fish, and some zooplankton. Hypoxic events on the shelf will be more frequent and more severe, leading to benthic mortality (e.g., Dungeness crab). Cold and windy coasts through summer will impact fishing (most recreational and some commercial boats won't go out for salmon) and may impact tourism (due to cold/unpleasant conditions). However, the cool conditions may provide refuge from inland heat leading to increased tourism from inland areas. More fog in summer because of temperature differential between coastal cool waters and inland heat. Fog will be persistent and coastal areas will benefit from reduced heat and precipitation.

In winter, runoff is weaker than previously and occurs in a shorter season. The flushing of estuaries and bays does not occur (some small bar-built estuaries stay closed all winter, trending towards coastal lakes/marshes), allowing for buildup of organic material and increasing hypoxic events (e.g., Pescadero Lagoon). The absence of large plumes from San Francisco Bay and Russian River associated with rain and snow melt deplete the mud belts on the shelf and benthic communities are impacted. Without winter south winds and freshwater plumes, there is a

reduction in northward currents and larval dispersal patterns change with loss of some coastal species due to southward "washout" – this is aggravated by stronger northerly winds and southward transport during upwelling. An absence of plumes and little stratification in the Gulf of the Farallones results in deep mixing, which limits light for primary production. In the absence of winter storms, upwelling occurs earlier in spring, leading to more productivity in spring and summer (winter primes summer). Also many people will enjoy fishing (crabs) and recreation (beaching, kayaking, etc.) – the mild sunny days in winter along the coast will become well known and draw in many seasonal visitors for beaching and boating. In summer, more foggy days may result in reduced number of people at beaches. With reduced southerly storm waves in winter and increased northerly waves during upwelling, accelerated erosion of north-facing beaches may occur. Though coastal retreat is generally anticipated across scenarios due to SLR, south-facing beaches in this scenario may experience less erosion relative to the other scenarios.

Habitat Impacts

Beaches and dunes:

- Reduced tourism in summer due to cold and fog may have economic impacts on communities; however, more tourists from the Central Valley may escape the heat on the coast perhaps offsetting tourism losses due to poor weather. Even so, drier, mild conditions early in winter/spring will offer good conditions.
- Erosion of north facing beaches and decreased erosion of south facing beaches. Much of the study area open coast is generally south facing, so in general this change could lead to decreased beach erosion, relative to the other scenarios.
- In south-facing dune systems, dune wetlands may receive reduced winter rain and undergo fewer dune blowouts/wave overtopping due to decreased erosion.
- North facing dune systems may suffer increased erosion.
- Rough summer conditions may lead to increased rescues of abalone divers, kayakers and other vessels.

Outer coast estuaries:

- Potentially severe impacts to salmonids from prolonged closure of creek mouths, less freshwater input, low lagoon water levels, and reduced nearshore productivity. However, reduced winter storms may be beneficial to salmonids because fewer juveniles will be washed out early due to lack of winter refugia.
- Increased OA will impact many invertebrate and fish populations, commercial oyster growers, sport and commercial crab fishery, and potentially other key species at the base of the food web.
- Reduced sediment transport from coastal watersheds could decrease the total area of mudflat habitat within the study region.

Rocky intertidal:

- Increased OA will impact many invertebrate and fish populations, commercial oyster growers, sport and commercial crab fishery, and potentially key species at the base of the food web.
- Rough summer conditions increase emergency rescues of abalone divers.
- Nearshore algae, cyanobacteria, and vascular marine plants (surfgrass) might benefit from the increased HCO_2 (acidic) environment. OA effects on seagrasses and marine macroalgae. Prevalence of surfgrasses influence tide pool temperatures and promote diversity of native invertebrate species. Temperature and community consequences of the loss of foundation species: surfgrass (*Phyllospadix* spp. Hooker) in tidepools.

2) Cold and Wet (increased runoff with wetter winters, stronger upwelling with foggier summers)

Scenario Narrative

Beaches and cliffs erode during winter storms, but without rebuilding through deposition during summer due to local high-frequency waves. In the winter, strong winds associated with cold fronts are more frequent. These storms bring increased runoff from local watersheds and the San Francisco Bay and delta (Bay). Relatively warmer winters with less snow in the Sierras increases winter runoff from the Bay and an earlier, more even plume of winter rainwater from the Bay and other coastal rivers.

Strong north winds in spring and summer drive upwelling, with high nutrient fluxes supporting productive bays and sheltered coastal waters – but in open shelf waters phytoplankton blooms occur farther offshore due to offshore transport, leaving nearshore systems less productive with impact on birds, whales and out-migrating salmon. But fixed kelp does well, as does the community that feeds on it. Cold and windy coasts through summer impact fishing and tourism.

Due to high runoff, the seasonal timing of the transition to upwelling doesn't change much from current conditions. Increased freshwater from winter runoff leads to lower salinity in bays and along the outer coast where freshwater plumes extend. Ocean water is drawn into bays and brings high-nutrient/relatively hypoxic/OA effects into bays. Higher winds and large storms in winter lead to greater movement of sand on beaches and dunes. In the winter, winds associated with storms tend to be from the south potentially facilitating northern transport of planktonic species. Winter outflow from the Bay will travel as far north as Point Arena leading to a decrease in salinity within the region, particularly. Small creek mouths in coastal watersheds will stay open longer in the summer, facilitating the movement of nutrients and biogenic material to nearshore environments but also potentially contaminants.

Because of greater frequencies of storms, there is a greater chance that storms will occur during extreme high tides (king tides) increasing the likelihood of coastal flooding. Coastal erosion, particularly on coastal cliffs, barrier beaches (Stinson Beach), and estuaries will increase which will increase turbidity of nearshore waters.

Habitat Impacts

Beaches and dunes:

- Nearshore productivity will decrease, limiting success of some nesting seabirds and other nearshore species.
- Despite increases in offshore primary productivity, birds, seals, and other beach species may not benefit and be under stress: increased erosion from storms will reduce current shoreline habitat for roosting and breeding. As storm wave directions change to the south, southward facing beaches may be more affected.
- Increased erosion of coastal cliff areas – public hazards. Potential temporary loss of pocket beaches along the cliff backed coast. Depending on cliff composition, pocket beaches may reform over time.
- Back-beach and inland flood occurrences will increase, altering habitats, vegetation, and adjacent coastal infrastructure more frequently.
    - Possible benefits to species like tidewater goby.
    - Back dune ponds form during wet winter events which may benefit species such as winter waterbirds and shorebirds.
    - Flood waters may mobilize and spread pollutants and HABs more widely.
- Sunny beach days throughout the year will not be as prevalent, and public-use space on the coast will decrease, displacing recreation impacts to recreation areas further inland.

Outer coast estuaries:

- Lower salinity may affect the success of some estuarine species such as eelgrass and *Gracilaria* algae.
- Seasonal decreases in primary productivity in some areas (Bay) reduces success of many species - alters food web.
- Increased access for salmonids in streams and sustained waters in streams carries over into summer. Pacific Herring benefit from increased freshwater runoff and suffer during drought conditions.
- May get increase of hypoxic events due to increased nutrients/deep-water intrusion – however, increased storms and runoff – hypoxic events may be more localized and dependent on circulation.
- Increased flooding will put stress on vegetation/marshes and their habitat specialists (e.g., Black Rail, Ridgeway's Rail) and infrastructure.

Rocky intertidal:

- Rocky intertidal may see decrease in primary productivity with impact to many species and ecosystems in those areas.
- Possible benefit from cool, foggy summers that prevent desiccation.
- Increases in mixing and currents from storms may increase invasive species.
- Increased storms damage/remove kelp-forest canopies: changes to kelp-dependent food webs and removal of some habitats.
- Increases in flooding/waves may put pressure on sessile species.
- Increased freshwater in tide pools may negatively affect surfgrass.
- Increased erosion of adjacent cliff areas – public hazards and burying of habitat.

General/regional impacts:

- Sport fishing may increase in offshore areas due to increases productivity leading to more boat traffic in general.
- U.S. Coast Guard use increases (accidents, spills, illegal activities).
- Fisheries management - may need to review and update limits/permits -- different approaches between nearshore/Bay and offshore fisheries.
- Surfing conditions improve in winter - but conditions also get more hazardous.
- Overall decrease in summer-time beach tourism due to fog - impacts to local communities' economies, utilities use.
    - Alternatively, residents of the Central Valley seeking heat relief may flock to coastal areas.
    - Local chambers of commerce/businesses may promote off-season tourism/other attractions.

3) Warm and Dry (less runoff with drier winters, weaker upwelling with warmer summers)

Scenario Narrative

The decrease of winds will cause less upwelling leading to fewer nutrients and less primary production. However, there will be less movement of nutrients offshore than in the high upwelling scenarios. So offshore productivity declines while the productivity in nearshore systems increases. Decreased offshore primary productivity is likely to lead to a decrease in reproductive success for seabirds. The higher acidity waters that are brought to the surface are processed quickly so less of an increase in acidity. Sea surface temperatures will be warmer than historically. We will see a decrease in localized hypoxic events, but HABs may be more prevalent inshore.

Less runoff means less stratification in nearshore and smaller inputs of biogenic materials and contaminants. Less runoff leads to higher salinity particularly in estuaries. Creek mouths will be

closed longer potentially reducing water quality in those creeks and their lagoons. Fewer storm events leads to more offshore stratification because there is less mixing.

Habitat Impacts

Beaches and dunes:

- Greater build-up of beaches with fewer winter storms and less windy days.
- Increased public use of beach.

Outer coast estuaries:

- Salinity levels may rise due to less water exchange as well as less freshwater input.
    - May affect growth and survival of organisms.
- Likely seasonal decreases in dissolved oxygen due to increasing sea surface temperature (SST) and salinity levels leading to pockets of hypoxia.
    - Hypoxic events to increase due to creek mouth closures.
- Creek mouth closures - decrease in water quality conditions and stagnation.
- Harmful algal blooms may be more prevalent in estuaries because of stagnation and warmer water. Also, potential for dieoff of water birds due to botulism.
- Pacific Herring and salmonid productivity declines due to less runoff of freshwater and mixing of estuaries.

Rocky intertidal:

- Warmer SST, decrease in winds, and less fog likely to increase thermal stress on rocky intertidal.
- Tidepools likely to suffer greater number of days with increased temperature, both mobile and sessile organisms will be subject to thermal stress.
    - Will affect larval and early stages of some subtidal/pelagic fish that recruit to intertidal.
- Disease transmission and toxic algal blooms likely to impact rocky intertidal communities/species more intensively.
- Invasive species - a decrease in winds and water movement may inhibit species migration, however, warmer SST may allow for introduction of new species or expanded range of existing non-natives.
- Decrease in upwelling and wind movement is likely to affect recruitment to rocky intertidal although this may vary spatially.
    - Likely to also affect food web (predator size and abundance both decrease).

4) Warm and Wet (stronger runoff with wetter winters, weaker upwelling with warmer summers)

Scenario Narrative

Strong runoff due to increased winter storms leads to an increase in biogenic material into coastal waters. Decreases in upwelling results in less offshore transport, lower offshore productivity and higher pelagic productivity. However, if inputs (biogenic material and inorganic nutrients from terrestrial runoff) are extremely high, hypoxia below plumes could increase, leading to the emergence of dead zones near plumes. Stratification will increase during winter months with increasing runoff events; however, this will also be disrupted by large storm events that will mix waters with large wind waves. Higher runoff will lead to lower salinity, particularly in estuaries. Outside of the rainy season stratification decreases. Sea surface temperatures will be warmer year-round.

Southern winds during winter storms will facilitate northern transport. The lower spring and summer northern winds may result in a longer period during which northern transport is facilitated. Spring transition period may be delayed due to lower spring northern winds causing a mismatch for food webs. Coastal erosion and flooding are likely in winter months due to wet winters. Water quality in pelagic areas decreases with increased turbidity and increases locally in toxic contaminants.

Late Fall/Winter:

- Coastal areas experience periods of intensified storm activity, particularly from the south and south-west, with at least some activity due to the type of atmospheric "river" known as "the pineapple express."
- Boosted rainfall increases inland erosion, flooding, and runoff, and larger waves and swells driven by strong southern and southwest winds increase disturbance along the coast, particularly on south- and southwest-facing coastlines.
- Freshwater runoff increases the amount of biogenic and contaminant material transported from land into the estuaries and nearshore habitats and can generate plumes of silty, less salty water that stretches for miles from river mouths. During storms and under windy conditions, the plumes mix with ocean waters resulting in increases in turbidity, and concentrated nutrients and contaminants in coastal and offshore waters.
- Increased nutrients fuel water column and benthic environments, although turbid waters limit photosynthetic activity.
- In between storms, the plumes and adjacent ocean waters can experience warming with less mixing and may eventually stratify, resulting in localized plankton blooms in upper waters and hypoxic conditions in deeper waters.
- Strong southern and southwest winds, as well as freshwater runoff, will accentuate northern currents, resulting in a dominance of northward transport. Southern and

southwest winds, as well as large storm waves, can increase sea level, leading to more inundation of coastal areas and alteration of immersion times of rocky intertidal zones.

Spring/Summer/Early Fall:

- Coastal areas experience warm stratified waters and light winds but there is an increased potential for more southern moisture and tropical storm influence (note increased thunderstorm activity during the summer of 2015 and "atmospheric river-like" extension from Hurricane Guillermo on August 4th and 5th 2015).
- The decrease in northerly winds means less upwelling in spring and summer with the upwelled water being warmer and containing fewer nutrients. Declines in upwelling leads to lower productivity, particularly within offshore waters. If winds die down and upwelled waters become stratified, then localized plankton blooms can occur.
- Since the upwelled water is from shallower depths, the increases in ocean acidity and decreases in dissolved oxygen are not as substantial as those associated with deeper upwelled waters; as a consequence, pulses of increased acidic water are less common and hypoxic events on the shelf are rare.
- Reduced upwelling also results in higher sea levels in spring and summer, which enhances the levels seen during spring tides and the increases associated with climate change.
- The number of foggy days also may be reduced with fog burning off more quickly.
- The hotter days in non-coastal areas and the calm conditions along the coast bring more visitors to the area to visit the beaches and rocky intertidal areas, explore and enjoy the nearshore coastal waters, or go fishing for southern species that are becoming more common (including pelagic species such as tunas and nearshore species such as California barracuda).

Multiple Year: Several climate oscillations will likely amplify or dampen the effect of this scenario. The Pacific Decadal Oscillation (PDO) fluctuates between a warm and cool phase, each of which may persist over several decades, with its primary signature most evident in the North Pacific. The El Nino/Southern Oscillation also has a warm (El Niño) and cool (La Niña) state that typically persist 6-18 months, with its primary signature most evident in the Pacific Ocean tropics. During a PDO warm phase with a strong El Niño event, the conditions described above could be amplified while conditions could be dampened during a PDO cold phase with a strong La Niña event.

Habitat Impacts

Beaches and dunes:

- Due to the predominant southern winds, south-facing beaches will be impacted more by storm swells and waves and will tend to have less sand than northern beaches.

- Likewise, dunes along south facing coastal shores will be impacted more by storm waves and winds than those along north facing coastal shores.
- Coastal strand width will be reduced due to increased sea level from both southern winds and decreased upwelling (in addition to sea level rise from climate change), particularly during winter storms and spring tides.
- Wrack on beaches (from terrestrial sources, sea grasses, and drift algae) will increase during winter, decrease during summer.
- Due to high disturbance in winter, reduced wrack in summer, and reduced plankton productivity in spring/summer, beach productivity likely will be reduced which could impact shore bird populations.
- Beaches may be periodically closed during winter due to increased contaminants from rivers.

Outer coast estuaries:

- Increased mixing within estuaries during winter months could result from increased freshwater flows due to higher runoff, increased saltwater flows due to larger swells and waves plus enhanced sea levels, and increased winds, tidal mixing, and density gradients.
- Large runoff events will move sediments and woody debris into the estuaries.
- Large runoff events will widen channels between the estuaries and the ocean, and will scour out estuaries, moving sediments from the estuaries into the ocean.
- Scouring may also impact important estuarine habitats such as eel grass beds.
- Increased sea level from both southern winds and decreased upwelling (in addition to sea level rise from climate change) will inundate estuarine habitats, particularly during winter storms and spring tides.
- Decreased mixing (and increased stratification) within estuaries during summer and early fall months could result from decreased freshwater flows (warmer storms = less snow pack) and calm water conditions offshore (less ocean flow into the estuaries) although sea levels will be enhanced.

Rocky intertidal:

- During winter months, rocky intertidal areas along southern shores will be disturbed more by large storm swell and waves than those along northern shores (since most storms will be from the south or south-west). On other hand, the areas along northern shores could more likely be buried by sand than those along southern shores.
- During winter months, rocky intertidal areas close to estuary mouths will likely experience lower salinity, more turbid waters for longer periods of time. There is also the potential for increased exposure to contaminants transported from terrestrial sources.
- Increased sea level from both southern winds and decreased upwelling (in addition to sea level rise), particularly during winter storms and spring tides, will expose some rocky

intertidal habitats to longer periods of submersion, and will likely submerge, on a more frequent basis, high intertidal habitats that rarely experience any inundation.

- Warm, less productive waters mean less food for rocky intertidal filter feeders. Localized plankton blooms resulting from nutrient –enhanced waters that become stratified (e.g. upwelled waters in spring and summer, or increased nutrient concentrations from runoff) may occur, but also may contain high concentrations of harmful algal species. The toxins from these planktonic algae accumulate up the food chain and can be lethal to top predators such as birds and mammals.
- Increased exposure to warmer air temperatures and potentially drier air conditions (from reduced presence of fog) during low tides, and warmer ocean temperatures during high tides could impact species populations and community structure.
- Water temperatures in tide pools might rise – causing a shift in species composition. Also, drier coastal conditions might increase the frequency of fires along the coast. Then, in the subsequent rainy winter, erosion transport could bring increased nutrients, carbon, and debris into the rocky intertidal (and estuarine) zones.
- Calm, warm conditions may result in more human activity along the coastal zone and thus more disturbances to the rocky intertidal habitats.

Nearshore:

- Reduction of offshore marine water productivity results in decreased forage populations which impact sea bird production and juvenile marine mammal survival.
- Warm, stratified waters with fewer nutrients in the summer and larger swells and waves from southern storms in the winter reduce kelp biomass and impact kelp-associated communities. Warm, less productive waters also mean less food for nearshore filter feeders. Localized plankton blooms resulting from nutrient enhanced waters that become stratified (e.g. upwelled waters in spring and summer, or increased nutrient concentrations from runoff) may occur, but also may contain high concentrations of harmful algal species. The toxins from these planktonic algae accumulate up the food chain and can be lethal to top predators such as birds and mammals.
- With warmer waters and a dominance of northward transport, southern species become more common. Species that reproduce better in cooler waters (e.g. certain species of rockfish) become less common.
- Calm, warm conditions lead to more fishing within nearshore waters.

Appendix B. Commonly used terms and acronyms

Bioswales - stormwater runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters. Bioswales improve water quality by infiltrating the first flush of storm water runoff and filtering the large storm flows they convey[1].

Climate-smart - The intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities[2].

Ecosystem service – any positive benefit that wildlife or ecosystems provide to people.

Grey infrastructure – manmade, engineered components of a system, including (but not limited to) seawalls, riprap, roads, levees, culverts.

Horizontal Levee – a term coined by The Bay Institute, this refers to a novel levee concept that uses vegetation on a gradual slope to protect from storm surge and waves instead of a vertical wall. It incorporates a brackish marsh that functions as a self-maintaining levee, building in elevation as plant root systems expand. It accelerates vertical growth of the marsh plain in order to keep pace with sea level rise[3].

Introduced species – a species (including any of its biological material capable of propagation) that is non-native to the ecosystem(s) protected by the sanctuary; or any organisms into which genetic matter from another species has been transferred in order that the host organism acquires the genetic traits of the transferred genes[4].

Invasive species – a species that is 1) non-native to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health[5].

Living shoreline – a natural alternative to hardened shorelines to protect from erosion and storm surge, living shorelines may include beaches and dunes, oyster reefs, or vegetation.

---

[1] Natural Resources Conservation Service: www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_029251.pdf

[2] Stein, B.A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. Climate-Smart Conservation: Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, D.C.

[3] The Bay Institute. 2013. Analysis of the Costs and Benefits of Using Tidal Marsh Restoration as a Sea Level Rise Adaptation Strategy in San Francisco Bay.

[4] GFNMS Management Plan

[5] Presidential Executive Order 13112 (February 1999)

LCP – Local Coastal Program, a planning tool used by local governments to guide development in the coastal zone, in partnership with the Coastal Commission.

OA – Ocean Acidification, the process by which uptake of carbon dioxide from the atmosphere causes a decrease in seawater pH.

Rolling easements - a legally enforceable expectation that the shore or human access along the shore can migrate inland instead of being squeezed between an advancing sea and a fixed property line or physical structure. The term refers to a broad collection of legal options, many of which do not involve easements. Usually, a rolling easement would be either (a) a law that prohibits shore protection or (b) a property right to ensure that wetlands, beaches, barrier islands, or access along the shore moves inland with the natural retreat of the shore[6].

TMDL – total maximum daily load, a regulatory term in the U.S. Clean Water Act, describing a value of the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.

[6] Titus, J.G. 2011. Rolling Easements. Climate-ready estuaries program. www.epa.gov/sites/production/files/documents/rollingeasementsprimer.pdf

Appendix C. Agency Designations

BCDC – Bay Conservation and Development Commission
BLM – Bureau of Land Management
Caltrans – California Department of Transportation
CCC – California Coastal Commission
CDFW – California Department of Fish and Wildlife
Coastal Conservancy – California State Coastal Conservancy
DWR – Department of Water Resources
EPA – Environmental Protection Agency
FEMA – Federal Emergency Management Agency
GGNRA – Golden Gate National Recreation Area
LiMPETS – Long-term Monitoring Program and Experiential Training for Students
MARINe – Multi-Agency Rocky Intertidal Network
MBNMS – Monterey Bay National Marine Sanctuary
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
NPS – National Park Service
NRCS – Natural Resources Conservation Service
OSPR – Oil Spill Prevention and Response
OST – Ocean Science Trust
Point Blue – Point Blue Conservation Science
PISCO – Partnership for Interdisciplinary Studies of Coastal Oceans
PRNS – Point Reyes National Seashore
RCD – Resource Conservation District
RWQCB – Regional Water Quality Control Board (North Coast and San Francisco Bay)
Sanctuary – Greater Farallones National Marine Sanctuary
SFPUC – San Francisco Public Utilities Commission
State Lands – California State Lands Commission
State Parks – California Department of Parks and Recreation
SWRCB – State Water Resources Control Board
TNC – The Nature Conservancy
UCSC – University of California, Santa Cruz
USCG – United States Coast Guard
USFWS – United States Fish and Wildlife Service

Appendix D. Strategy List

Attached to this report is a content-protected and sortable excel file of all strategies developed by the Working Group. This file was requested by the Working Group as a means for agencies to sort the strategies by column and search by key word, while retaining protected content. The search and sort properties of this file do not work on Mac computers.