# GREATER FARALLONES NATIONAL MARINE SANCTUARY

# Climate Action Plan

**November 2016**

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL MARINE SANCTUARY PROGRAM

## ABOUT THIS DOCUMENT

The Climate Action Plan (Plan) is the result of a 2-year process to characterize climate impacts and vulnerabilities to Sanctuary resources along the North-central California coast and ocean (figure 1: Study Area Map), and to develop management strategies to respond to and decrease those vulnerabilities, ultimately enhancing resource resilience to climate impacts. The Plan represents the culmination of a Sanctuary Advisory Council (Council) planning process that resulted in the development of 78 adaptation strategy recommendations for the region's management agencies to take to enhance coastal habitat resilience (Appendix B). The Plan presents the final adaptation strategies from these recommendations that Greater Farallones National Marine Sanctuary (Sanctuary) would like to pursue, including a few additional strategies proposed and finalized by staff.

To learn more about the vulnerability assessment that provided the informational foundation for this work, see http://sanctuaries.noaa.gov/science/conservation/vulnerability-assessment-gfnms.html. To learn more about the working group process that informed this Plan, refer to the Council's final Climate-Smart Adaptation Report: http://farallones.noaa.gov/manage/climate/pdf/Climate-SmartAdaptationReport.pdf.

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NATIONAL MARINE SANCTUARIES
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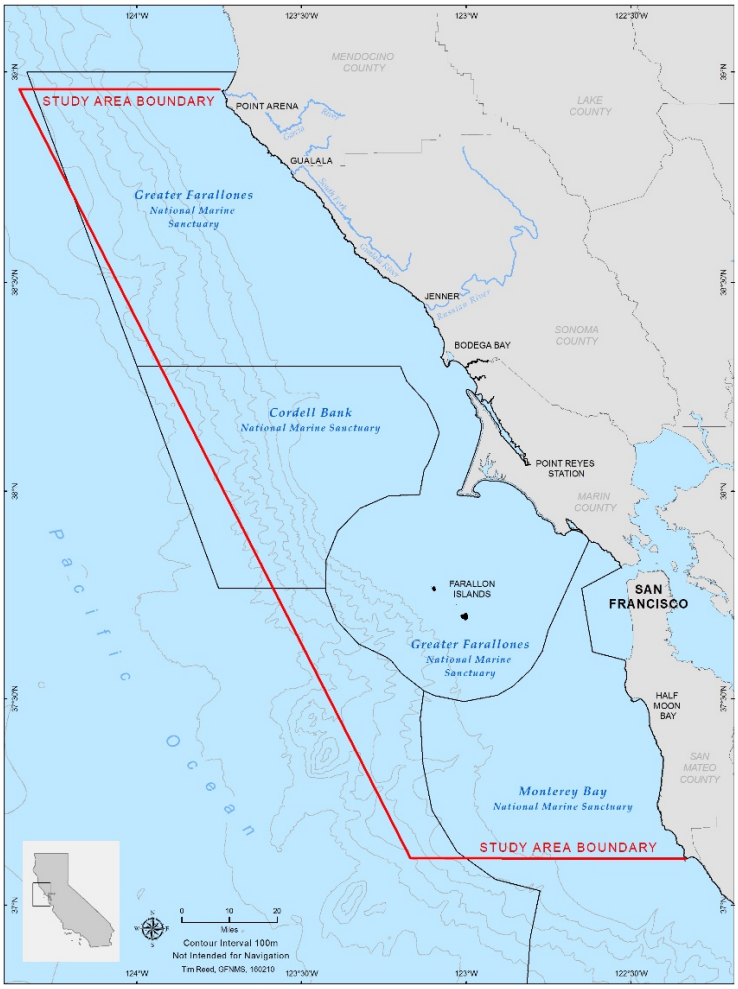
## INTRODUCTION

### Purpose and Need




The specifics of climate change impacts on the Sanctuary's coast and ocean resources were largely unknown when the Ocean Climate Initiative was founded in 2008. With the inaugural Ocean Climate Summit that year, the need to develop a program that could investigate climate impacts specific for our region and plan for anticipated changes on a local scale became apparent. In the years to follow, the science of climate change and its regional impacts were reviewed in an exhaustive literature survey that resulted in the Climate Impacts Report (Largier et al. 2010); physical and biological indicators of climate change were selected and investigated in the Indicators Monitoring Inventory and Plan (Duncan et al. 2012); climate vulnerability of the region's most critical species, habitats and ecosystem services were assessed in the Vulnerability Assessment Report (Hutto et al. 2015); and strategies to address those vulnerabilities for coastal habitats were identified in the Climate Adaptation Report (Hutto et al. 2016). Each of these reports presented Sanctuary management with recommendations to advance climate change understanding and action. This Plan represents the culmination of these efforts, but also marks the beginning of the transition from planning to climate action for the Sanctuary, building on and strengthening partnerships with other agencies, academic institutions, and non-profit organizations.

### Goal

The goal of the Plan is to lay the foundation for implementing management actions to achieve the Climate Program's vision of a healthier North-central California coast and ocean (Figure 1) that is more resilient to climate change. By implementing living shorelines, promoting education, protecting and restoring habitat, limiting human disturbance, eliminating, to the extent possible, invasive species, and investing in science needs, the Sanctuary can effectively enhance resource resilience to climate impacts and ensure the health and viability of the Sanctuary's natural resources.

**Process**

At the August 2014 meeting of the Sanctuary Advisory Council, the Climate-Smart Adaptation Working Group was formed to act on the recently completed Vulnerability Assessment Report (Hutto et al. 2015). The goal of this group was to develop and prioritize climate-smart adaptive management recommendations that could 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. The working group met five times over the course of the 2015 year, from April to December, to develop management recommendations for the three habitats identified as most vulnerable in the assessment (Hutto et al. 2014): beaches and dunes, outer coast estuaries, and rocky intertidal. Their 84 final adaptation recommendations were presented to the Council in March 2016 and 76 of those were approved with revisions, and two additional strategies were added (Appendix B). 41 of those are beyond the Sanctuary's management scope and authority, and have been forwarded to the appropriate management entity. The Sanctuary Superintendent and Program Coordinators then reviewed and discussed the 31 strategies that were identified for Sanctuary implementation and approved 23 strategies for inclusion in this Plan. Three additional strategies were added, for a total of 26 strategies presented in this Plan. Because the development of the strategies in this Plan focused solely on the Sanctuary's most vulnerable coastal habitats, new strategies were added by staff to address the most vulnerable offshore species (Hutto et al. 2015) that would not directly benefit from the strategies already identified: SN-5 for deep-sea coral communities; HD-3 for the blue whale and other large baleen whales; and SN-6 for monitoring of ocean conditions to track the impact of ocean acidification on pteropods and other water column indicator species.

**Scope**

These strategies do not represent the entirety of what can be implemented to reduce vulnerability of coast and ocean 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 funding, legal, and methodological considerations by the Sanctuary on a case-by-case basis. 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. Some strategies are more general in nature or are presented in a simplified context. These will require additional detail depending on the location of implementation. All strategies will require additional funding to investigate viability and implementation.

This Plan is intended to be a living, adaptive document that should be updated as research advances and circumstances change. To ensure that this plan is meeting its goal and objectives, it will be periodically reviewed and evaluated to ensure that it is responsive to emerging issues and changing climate impacts. Implementation of the proposed actions is contingent upon availability of funding; therefore, modifications to the strategies and activities may need to be made due to unforeseen circumstances. Next efforts will be to identify priority issues, determine which strategies are within the management authority of the sanctuary to implement, determine the project's budget and funding needs, and identify funding sources.

## PROPOSED STRATEGIES

| Approach | Strategy | Actions |
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| **Implement Living Shorelines (LS)** | LS-1: *In areas dominated by grey infrastructure, identify potential demonstration sites for nature-based infrastructure projects and/or other "active management" projects; implement and evaluate effectiveness to inform future efforts across the region.* | LS-1.1: Identify locations within estuaries that are currently impacted by flooding and erosion, where nature-based shoreline protection projects could have co-benefits for natural systems and human communities, and will not impact current protections for unique habitats or further threaten Endangered or Threatened Species. Analyze net environmental benefits to inform site selection. |
| | | LS-1.2: Based on characteristics of the site, identify the appropriate nature-based infrastructure project to implement. |
| | LS-2: *To the extent practicable, reduce or modify armoring that exacerbates erosion.* | LS-2.1: Identify locations with armoring that exacerbates erosion. Analyze net environmental benefits to inform site selection for modifying structures |
| | | LS-2.2: Replace armoring with nature-based solutions such as natural material to create sloped, transitional habitat (e.g. native oyster reef or dune). |
| | | LS-2.3: If armoring can't be removed and replaced, implement living shoreline techniques in conjunction with new construction or repairs. |
| | LS-3: *To the extent practicable, remove/redesign roads in locations that act as barriers to natural expansion of coastal habitats. Always remove roads where possible; if not possible, redesign the road.* | LS-3.1: Identify areas that: A) are critical for coastal habitat expansion and that have roads that impede migration, and B) have roads vulnerable to sea level rise, flooding, other climate impacts. |
| | | LS-3.2: Develop a "Climate-Ready Response" plan for identified locations to allow for road removal/redesign in case of a disaster (e.g. road is damaged from a flood event). |
| | | LS-3.3: Post-disaster (flooding/road failure): implement the "Climate-Ready Response" plan to move/redesign road to enhance future resilience. |
| | | LS-3.4: If road is not impacted by climate change/extreme events, remove/redesign the road as available during standard maintenance schedule timeframes (i.e., when the opportunity arises to replace/redesign the road). |
| | | LS-3.5: 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). |
| **Promote Education (E)** | E-1: *Develop a Climate Education Plan to detail and document the incorporation of climate change messaging, stories, and solutions into existing education programs.* | E-1.1: Developed by the Education Program Coordinator, this Climate Education Plan will consider the latest climate change and ocean acidification science and outreach/education techniques. This plan will be a living document that captures existing programming and suggests new programming. |
| | | E-1.2: Update the Climate Education Plan every 5-10 years. |
| | E-2: *Enhance tidepool education and interpretation programs through training and guidance to communicate the implications of climate change and the exacerbating stressor of tidepool* | E-2.1: Develop a common training core for docents that includes climate change impacts and the exacerbating stressor of tidepool visitation and recreational extraction on intertidal habitats, as well as tidepool etiquette and safety and the impact that impaired safety will have on natural resources. (e.g. boat groundings and the impact of emergency response). |

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| | *visitation and recreational extraction on coastal habitats.* | E-2.2: Work with the Friends of Fitzgerald Marine Reserve to incorporate this training into their existing training. |
| | | E-2.3: Train existing outdoor education staff that lead public tidepool trips to use this common training in their programming (e.g. San Mateo County outdoor education school, Exploring Your Horizons, San Juaquin Outdoor Ed). |
| | | E-2.4: Build on the Rocky Shore Docent Training Program that was developed by GFNMS and California Academy of Sciences to incorporate new climate change messaging into docent training material. Hold new training sessions with existing and new docents, and expand the program to include other highly-visited tidepools (e.g. Pillar Point, Bean Hollow, and Pigeon Point). |
| **Protect and Restore Habitat (H)** | H-1: *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.* | H-1.1: Identify and prioritize areas that are currently being impacted by sediment-disruptors, and remove where possible. |
| | | H-1.2: If the structure cannot be removed, then work with partners to enable managed retreat (for bluffs to feed the beach as sea level rises) and support beach nourishment to control coastal erosion. |
| | H-2: *For locations identified as having appropriate substrate available under eroding coastlines for potential colonization and creation of new intertidal habitat, allow those areas to erode to create new habitat. Discourage the creation of structures that would inhibit erosion.* | H-2.1: Identify locations where cliff erosion may allow for the creation of new intertidal sandy beach or rocky habitat and do not armor or protect those cliffs. Maintain intertidal habitat continuity north to south - avoid where possible large stretches of total inundation and loss of intertidal habitat. |
| | | H-2.2: Create unfettered sea-to-land linkages for new habitat development by allowing cliffs in these locations to erode naturally. |
| | H-3: *Protect and restore eelgrass in areas that have been adversely affected by human activities, and where restoration will have co-benefits (reducing wave energy and erosion).* | H-3.1: Identify most critical locations in need of eelgrass restoration and/or protection, potentially including Tomales Bay, Esteros de San Antonio and Americano, and Bolinas Lagoon, and analyze net environmental benefits to determine if restoration is a viable option. |
| | | H-3.2: As the Eelgrass Research Plan develops (see SN-3.2), adapt management and restoration plans to account for new information. Do not pursue eelgrass restoration until the most critical research questions have been answered. |
| | H-4: *Restore lower intertidal mussel beds and algae, including sea palms (a species identified as vulnerable), to reduce impact of wave energy on intertidal zones by enhancing physical/structural resistance.* | H-4.1: Identify areas in need of restoration and prioritize intertidal reefs that are most vulnerable to wave energy and erosion. |
| | | H-4.2: Design feasibility studies and demonstration projects to test viability. |
| | H-5: *Restore surfgrass (Phyllospadix) and algal species to act as aqueous canopies to provide shading and reduce temperatures and evaporation in tide pools.* | H-5.1: Identify areas in need of restoration and prioritize intertidal reefs that are most vulnerable to prolonged exposure and heat stress. |
| | | H-5.2: Design feasibility studies and demonstration projects to test viability. |
| | | H-6.1: Identify locations that historically had bull kelp but are in need of restoration; ensure necessary conditions for |

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| | H-6: *Restore subtidal kelp forests to attenuate waves and buffer from enhanced storm activity.* | kelp settlement and growth are met (e.g. good light and water quality, little turbidity, rocky substrate) |
| | | H-6.2: Design feasibility studies and demonstration projects to test viability. |
| | H-7: *In the aftermath of an oil spill or other contaminant, ensure that restoration of affected areas takes into account climate considerations.* | H-7.1: Restoration plans should explicitly account for climate impacts on the successful restoration of affected sites, including the type of restoration, the location, net environmental benefits analysis, and what should actually be restored based on climate envelope modeling to predict what species will likely become dominant. |
| | H-8: *Let go of pocket beaches that can't retreat, and do not intervene with management actions.* | H-8.1: Identify beaches that can't be logistically nourished and have no options for retreat, and plan for the loss of these beaches. |
| **Limit Human Disturbance (HD)** | HD-1: *Manage access to rocky intertidal habitat that serve as climate change refugia.* | HD-1.1: Identify locations in the study region with functional rocky intertidal habitat that is less vulnerable to the impacts of climate change, including sea level rise, increased air temperatures, wave action, pH, and erosion, and may serve as climate refugia for rocky intertidal organisms. |
| | | HD-1.2: Identify site-specific methods to manage access to these areas to limit human disturbance. |
| | HD-2: *With the expectation that climate change impacts (such as those from storm activity and sea level rise) will reduce or change major marine mammal haul-outs and seabird nesting sites, provide protections for new sites, including climate change refugia.* | HD-2.1: Monitor historical haul-out and nesting sites, including Pescadero Rocks and Bean Hollow, to document changes in use by marine mammals and birds under varying conditions. |
| | | HD-2.2: Through seasonal monitoring, identify new marine mammal haul-out and seabird nesting sites. Prioritize the locations with the largest amount of disturbance to the largest breeding sites. |
| | | HD-2.3: Identify climate change refugia for use by marine mammals and seabirds, including beaches, cliffs, and rocky outcroppings that are less vulnerable to sea level rise, wave action, and erosion. |
| | | HD-2.4: Reduce human disturbance to identified sites, especially during times of heavy surf and inundation that will reduce availability of haul-out and nesting 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. |
| | HD-3: *Reduce acoustic impacts and ship strikes on large whales in the Sanctuary.* | HD-3.1: Support the implementation of the Vessel Strikes and Acoustic Impacts (2012) Report. |
| **Address Invasive Species (IS)** | IS-1: *Prevent non-native invasive species establishment (aquatic and terrestrial) in estuaries, rocky intertidal, and pelagic environments.* | IS-1.1: Identify invasive species that are of greatest threat to the Sanctuary and the capacity for management to prevent invasion. |
| | | IS-1.2: Identify areas that are vulnerable and susceptible to invasion. |
| | | IS-1.3: Depending on site characteristics, consider the following activities to prevent invasive species establishment:<br>- plant natives<br>- remove invasive species including those near or adjacent to sanctuary habitat |

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| | | - alter human behavior<br>- conduct inspections<br>- conduct targeted outreach |
| | | IS-1.4: Enhance education to recreational users and communities to prevent boaters, etc. from aiding in introductions. |
| | IS-2: *Clarify the definition of introduced/invasive/non-native aquatic and terrestrial species to take climate-induced changes into account. 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.* | IS-2.1: Review current Sanctuary regulations and determine if a revision is necessary to clearly indicate that climate-caused species migrations should be managed differently than human-caused species invasions. |
| | IS-3: *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*. | IS-3.1: Organize a workshop with regional monitoring programs (PISCO, MARINe, LiMPETS, PRNS, CDFW) to develop a rapid assessment program and/or determine if an existing program may adequately serve this role. Determine how to leverage existing efforts. |
| | | IS-3.2: Focus on existing sampling sites (e.g. MARINe), and include both less disturbed sites, and urban/highly visited sites like Fitzgerald and Duxbury where volunteers and visitors can be engaged. Leverage citizen science networks and programs. |
| | IS-4: *Following detection of invasive species, conduct rapid response of non-native invasive species removal to protect natural systems.* | IS-4.1: Develop an invasive response team, with clearly defined roles and responsibilities to respond rapidly to invasive species detection. |
| | | IS-4.2: Consider the characteristics of the invasive species and identify their abundance, distribution and capacity to manage (can they be eradicated?). Consider the following techniques for eradication: manual removal, flooding, fire in transition zones, reestablishing natives. |
| **Invest in Science Needs (SN)** | SN-1: *Conduct monitoring before and following natural extreme events to build on knowledge of climate change impacts to estuarine processes and to inform adaptive management.* | SN-1.1: Identify locations in the sanctuary that are most vulnerable to extreme events that result in coastal inundation and erosion. Establish baseline monitoring of these locations. |
| | | SN-1.2: In partnership with regional monitoring entities and land managers, develop an extreme event monitoring framework that sets in place the priority sites and factors to be monitored immediately following extreme events, as well as the critical partners and their roles. The following extreme events should be included:<br>- El Nino/La Nina events<br>- Extreme storms that result in coastal inundation and heavy precipitation |
| | | SN-1.3: Develop rapid response monitoring teams to employ the extreme event monitoring plan at select sites. |

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| | SN-2: *Determine the source of sediment for vulnerable beaches in order to improve sediment supply processes.* | SN-2.1: Identify beaches in the Sanctuary that are most vulnerable to erosion and sand loss and/or have unknown sediment sources. |
| | | SN-2.2: Working with the Coastal Sediment Management Workgroup and USGS, identify the source of sediment and develop management recommendations and permit requirements for sediment supply management. |
| | SN-3: *Promote estuarine research to enhance eelgrass restoration efforts.* | SN-3.1: Identify most critical research questions based on management needs for eelgrass restoration. Major research questions may include:<br>- Eelgrass distribution: what has caused the loss of eelgrass in Bolinas Lagoon and Pescadero Marsh?<br>- Do salinity and turbidity affect eelgrass establishment and persistence? |
| | | SN-3.2: Develop an Eelgrass Research Plan to inform management and restoration activities, start with Tomales Bay and Bolinas Lagoon. |
| | SN-4: *Pursue and encourage research in OA-mitigation methods that remove CO2 from seawater, following the recommendations of the West Coast Ocean Acidification and Hypoxia Panel (Chan et al. 2016).* | SN-4.1: Seek partnerships with technical experts to establish experimental treatment plots as part of a demonstration project to test the local mitigation of OA impacts and carbon sequestration through the protection and restoration of bull kelp and seagrass. |
| | | SN-4.2: From the demonstration project experimental plots, identify and inventory locations throughout the Sanctuary where OA mitigation and $CO_2$ removal can be accomplished through protection and restoration of bull kelp, wetlands, and seagrasses. |
| | | SN-4.3: Identify and map locations throughout the Sanctuary most vulnerable to ocean acidification. |
| | | SN-4.4: Develop an OA mitigation and restoration plan based on findings. Also consider the incorporation of findings into existing restoration plans, for seagrasses, wetlands, and bull kelp. |
| | SN -5: *To provide greater protection of critical biogenic habitats and key species, map the full extent of blue carbon habitat (seagrass beds, tidal marshes) and biogenic habitat (bull kelp beds, deep sea corals) in the Sanctuary.* | SN-5.1: Investigate seagrass as blue carbon habitat and complete seagrass mapping along the Sanctuary coast. Update CEC (2016) data based on survey sites where point data have already documented seagrass occurrence to create digital polygon maps of seagrass bed extent. |
| | | SN-5.2: Investigate saltmarsh as blue carbon habitat and complete saltmarsh mapping along the Sanctuary coast. |
| | | SN-5.3: Utilize Sanctuary blue carbon habitat as sites for carbon offset. Investigate funding for blue carbon habitat restoration as part of carbon efforts. |
| | | SN-5.4: Following kelp report recommendation (Springer et al. 2007), map extent of bull kelp forests and ground-truth aerial canopy cover estimates with diver-based estimates of kelp biomass. |
| | | SN-5.5: Complete mapping and characterization of sanctuary's deep-sea coral reefs. |
| | SN-6: *To track the impact of ocean acidification and inform the development of new protections, increase monitoring of pH,* | SN-6.1: Determine baseline pH and $CaCO_3$ levels in critical deep-sea coral reef habitat across the sanctuary, comparing the northern portion of the upwelling cell at Point Arena, to Rittenburg Bank, Deep Reef, Bodega Canyon, Farallon |

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| | *$CaCO_3$, and water column indicator species.* | Escarpment and Pioneer Canyon to determine which areas are in most need of additional protection. |
| | | SN-6.2: Increase sampling efforts of water column indicator species, e.g. pteropods, krill and foraminifera species, to track shell thinning and changes in recruitment to determine the degree of ocean acidification impact. |
| | | SN-6.3: Develop areas to be additionally protected by reducing or eliminating activities that degrade coral health or extract species that are most vulnerable to ocean acidification. |

## ISSUE STATEMENTS

This section provides issue statements to concisely explain the intent and justification for inclusion of each approach as a method of addressing the impacts of climate change. Strategies are organized by the following general approach to action: Implement Living Shorelines, Promote Education, Protect and Restore Habitat, Limit Human Disturbance, Address Invasive Species, Invest in Science Needs.

### Implement Living Shorelines

As sea level rise and increased storms exacerbate erosion, hardened structures (seawalls, bulkheads, etc.) are often used to stabilize shorelines. However, these stabilization techniques can often increase the rate of erosion and negatively impact the natural processes and habitat that natural shorelines provide. This approach includes strategies that call for the use of living shorelines as an alternative (i.e. natural materials such as sand and biogenic habitat such as seagrass and kelp beds, also referenced as "green infrastructure", "nature-based solutions" and "soft engineering") to reduce erosion and combat the effects of SLR and increased storms, while benefitting habitats and human communities.

Living shorelines also provide habitats with the opportunity to migrate inland or upland in response to sea level rise. Thorne et al. (2016) indicate that California tidal wetlands, including Bolinas Lagoon, will experience dramatic habitat transition by 2080 under mid-SLR projections and 2050 under high-SLR projections, with the complete loss of high and mid-marsh habitat. Protecting existing upland areas may ensure that high marsh habitat can persist locally, and will also likely provide flood and erosion protection for human infrastructure.

Multiple resources are available to guide and advise the use of living shorelines, including: Guidance for Considering the Use of Living Shorelines (NOAA 2015) and Use of Natural and Nature-based features for Coastal Resilience (Army Corps of Engineers 2015). The use of living shoreline techniques within San Francisco Bay are fairly well tested and demonstrated (see SF Bay Living Shorelines), but their application to wave-exposed systems like outer coast estuaries and beaches/dunes have received much less attention. Surfer's Point Managed Retreat Project in Ventura has demonstrated successful use of beach nourishment combined with infrastructure relocation and select living shoreline strategies to stabilize a vulnerable stretch of coastline in Southern California while avoiding traditional armoring. The Nature Conservancy is pursuing a

project to identify appropriate living shoreline techniques for sea level rise adaptation in coastal California.

**Promote Education**

Education is an essential element of the global strategy to adapt to climate change – it ensures that people understand the risks and impacts of climate change in their communities, encourages changes in behavior and attitude to mitigate those impacts, and provides the tools for communities to adapt to climate change (UNESCO 2016). The strategies in this approach address the need to educate and engage the local community in understanding the impacts of climate change as well as local efforts to reduce those impacts.

**Protect and Restore Habitat**

Habitat conservation is listed as one of seven collaboratively-developed goals in the National Fish, Wildlife, and Plants Climate Adaptation Strategy (2012) to help natural resources cope with the impacts of climate change, with the intent of protecting healthy populations of species and supporting ecosystem function. This approach to climate adaptation is often cited as one of the most important, if not *the* most important, action to take (Mawdsley et al. 2009, Heller and Zavaleta 2009). The following strategies seek to directly protect and restore habitat or key ecosystem processes in order to enhance the adaptive capacity of these systems to the impacts of climate change. This approach also identifies strategies that utilize habitat protection as a method of alleviating climate impacts by directly reducing climate stressors (specifically, increased storm activity and increased air temperature) on coastal habitats, species, and human communities.

Though some studies predict increased variability in air temperature (Largier et al. 2010), coastal fog is likely to decrease (Johnstone and Dawson 2010) and extreme heat events are predicted to increase for coastal areas (Ekstrom and Moser 2012). Increased air temperatures increase tidepool evaporation and water temperature, and exacerbate intertidal "bleaching" events, with negative impacts on intertidal algae and invertebrates. Winter storms have been increasing in frequency and intensity since 1948 (Graham and Diaz 2001, Zhang et al. 2004) and peak storm wave heights have been increasing along the Pacific Coast (Largier et al. 2010). Increased storminess leads to increased disturbance of coastal areas and temporarily elevated sea level. This stressor was identified as the number one most significant climate stressor for resources in the North-central California coast and ocean region (Hutto et al. 2015).

**Limit Human Disturbance**

Habitats that experience non-climate stressors may be more sensitive to climate changes (Hansen and Hoffman 2011). Human disturbance, via aircraft, vessels and recreation, was identified as the 3rd most significant non-climate stressor (out of 15) for resources in the North-central California coast and ocean region (Hutto et al. 2015). Rather than reduce access to highly vulnerable or impacted habitats, the strategies in this approach limit human disturbance to climate change refugia to ensure local persistence of relatively functional and intact habitat. Climate change refugia are defined as "areas relatively buffered from contemporary climate change over time that enable persistence of valued physical, ecological, and socio-cultural resources" (Morelli et al. 2016). Focusing protection on these areas is an effective means to

allocate limited conservation capacity (Morelli et al. 2016) and ensure that valued resources persist in the Sanctuary.

**Address Invasive Species**
Invasive species management is considered a "key tool" in addressing climate change impacts on natural systems and enhancing habitat resilience (Burgiel and Muir 2010). Invasive and problematic species were identified as the 2nd most significant non-climate stressor (out of 15) for resources in the North-central California coast and ocean region (Hutto et al. 2015) and the impact of invasive species is known to be exacerbated by climate change. Non-native species are known to alter species composition, threaten the abundance and/or diversity of native species, interfere with ecosystem function, and disrupt commercial and recreational activities (GFNMS 2008). This approach outlines multiple strategies to effectively manage the exacerbating stressor of invasive species, including prevention, detection, and removal, and should be considered in concert with the Introduced Species (IS) Action Plan (GFNMS 2008).

**Invest in Science Needs**
One of the key tenets of climate-smart conservation is adaptive management – the flexible and rapid response of management practices to new and changing information (Stein et al. 2014). "Science needs" refers to the information or products that are required in order to make an informed management decision. The strategies in this approach detail physical and biological monitoring and research that is needed to inform management responses to climate impacts by outlining the priority science needs for Sanctuary management.

## NEXT STEPS

**Implementation**
*Management Plan*
The goal of this plan is not to serve as a stand-alone reference for Sanctuary management, but rather to provide a basis for incorporation of climate considerations and related adaptation actions into pre-existing Sanctuary management documents. As the next management plan review approaches, Sanctuary staff will determine the best strategy for incorporating the strategies in this plan into issues-based (e.g. invasive species, wildlife disturbance) and/or program-based (e.g. Resource Protection) action plans. Additionally, to address the IS-2 strategy, Sanctuary staff will review our current regulations to ensure they are taking climate considerations into account and will consider revising the definition of introduced species appropriately.

*Living Shorelines*
Living shorelines implementation and habitat protection/restoration have been identified by Sanctuary Program Coordinators and the Superintendent as priority strategies for implementation. Through the Resilient Lands and Waters Initiative, and in partnership with local agency partners including Marin County, priority sites for implementation of living shoreline techniques have been identified. Additionally, through graduate student work at the Romberg Tiburon Center for Environmental Studies, the region's most vulnerable habitats and other

important features will be mapped alongside the Our Coast, Our Future sea level rise visualization tool and other climate modeling data. These mapping products will help the Sanctuary and partners select the most appropriate sites for implementation of living shoreline projects. Based on these sites, 2-3 conceptual plans will be developed, including conceptual design components and steps, project timeline, needed resources for each step of implementation, critical partners to engage at each step of implementation, and identification of required permitting/environmental review that must occur prior to implementation. During this time, overlapping and complementary efforts will be identified throughout the region to leverage partnerships and resources, and funding will be sought for implementation of plans. Initial conceptual review will be conducted by a living shorelines expert and project engineer.

*Science Needs*
The Climate Program Coordinator is currently working with the Conservation Science Coordinator to integrate the science needs identified in this Plan into the Science Needs documents developed to address critical management issues in the Sanctuary. This will likely include the invasive species strategies, estuarine protection research strategies for the Esteros, and strategies that seek to protect the rocky intertidal through demonstration projects and monitoring. These documents are critical to providing a direct science-to-management link for local researchers interested in contributing to sanctuary science that will inform management decisions.

**Maritime and Cultural Heritage**
While oral traditions speak of people from the dawn of time on the coast, little archaeological evidence is known about the Paleo- Indians of coastal Central California. By 11,000 years ago, the generally accepted date of earliest human habitation, sea level was already rising. But people may have come earlier, and evidence of that now lies in waters as deep as 300 feet. The Paleo-Coastal people may have either lived in the near-shore environment or lived inland and traveled to the shore to hunt and gather resources for their survival. Descendants of these Paleo- Coastal peoples have continued to use the sanctuary for traditional, customary, cultural, subsistence, spiritual, and religious practices. The sacred sites used for these practices may be at risk from sea level rise, and other impacts from climate change. The Ocean Climate Program reached out to tribal communities in the region to partner with local tribes to support their efforts to address the impacts of climate change on traditional tribal resources and culturally significant areas.

The sanctuary is also home to over 400 known shipwrecks, dating back to 1595. The site has begun a systematic examination of the known shipwreck sites, and has discovered several more. While little is left of the older wooden vessels, the more substantial iron and steel-hulled vessels exist close to shore as battered wrecks, and lie more intact in deeper waters of the sanctuary. The remains of the coastal lumber chutes and dog hole ports built on the face of rock ledges, moorings and wrecked vessels also exist within the sanctuary. To address the impact of climate change on shipwrecks and coastal artifacts, the following should be considered for next steps:

- Identify vulnerabilities of shipwrecks and coastal artifacts due to climate change, especially OA and SLR
- Work with ONMS Maritime Heritage team, and local, state and federal partners to add to what is known about our cultural landscape.

To complement the climate work that has been accomplished for sanctuary natural resources, it is recommended that the sanctuary convene a group of experts to complete a follow-up Vulnerability Assessment of maritime heritage assets and the cultural landscape and identify and prioritize adaptation strategies specifically for these resources.

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## Appendix A. Key Terms and Agency Acronyms

Key terms:
*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[1].

*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[2].

*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[3].

*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[4].

*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.

*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.

*SLR* – Sea Level Rise

[1] 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.
[2] 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.
[3] GFNMS Management Plan
[4] Presidential Executive Order 13112 (February 1999)

Agency Acronyms:

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
EPA – Environmental Protection 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
OSPR – Oil Spill Prevention and Response
OST – Ocean Science Trust
PISCO – Partnership for Interdisciplinary Studies of Coastal Oceans
PRNS – Point Reyes National Seashore
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
TNC – The Nature Conservancy
UCSC – University of California, Santa Cruz
USFWS – United States Fish and Wildlife Service

## Appendix B. Advisory Council Strategy Recommendations with Sanctuary response

Appendix B is attached as to this report as a content-protected excel file. All strategies recommended to the Sanctuary are included, and are color-coded based on their final determination: included in this Plan (yellow), eliminated entirely (red), retained for other agencies (white), and added by staff (green). Modifications to the strategies by staff are provided, and justification for elimination and addition are included.