Climate Adaptation Opportunities for US Pacific Breeding Seabirds

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List of Abbreviations:

BFAL = Black-footed Albatross
BOPE = Bonin Petrel
BSTP = Band-rumped Storm-Petrel
CCE = California Current Ecosystem

ESA = Endangered Species Act
GMA = Game Management Area
HAPE = Hawaiian Petrel
IPCC = Intergovernmental Panel on Climate Change
IUCN = International Union for Conservation of Nature
LAAL = Laysan Albatross
MBTA = Migratory Bird Treaty Act
MHI = Main Hawaiian Islands
NAR = Natural Area Reserve
NHP = National Historical Park
NISC = National Invasive Species Council
NEPA = National Environmental Policy Act
NESH = Newell's Shearwater
NM = National Monument
NWHI = Northwestern Hawaiian Islands
NWR = National Wildlife Refuge
NPS = National Park Service
NS = National Seashore
POSP = Polynesian Storm-Petrel
PRC = Pacific Rim Conservation
SMA = Special Management Area
TRSP = Tristram's Storm-Petrel
USFWS = U.S. Fish and Wildlife Service
USTP = U.S. Tropical Pacific

EXECUTIVE SUMMARY

Seabirds are one of the most threatened bird groups in the world and have been the focus of intensive conservation management in recent years. The USA is a global hotspot for seabirds and is home to 149 out of the world's 368 seabird species. This high species diversity is a function of the country spanning multiple ocean basins and a wide range of latitudes and habitats from the tropics to the arctic. The U.S. Tropical Pacific (USTP) and California Current Ecosystem (CCE) regions each host diverse seabird populations with unique ecological roles and distinctive threats. In the USTP, which includes Hawaii, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and the Pacific Remote Islands, invasive predators and rising seas threaten nesting areas on these tropical, low-lying islands. In the more temperate CCE, spanning California, Oregon, and Washington, seabirds face pressures from offshore development, prey shifts due to a warming current system, and human disturbances near coastal habitats. As part of efforts to combat the cumulative impacts of these threats, active seabird restoration efforts have grown in recent years. The two primary active seabird restoration methods used are social attraction, where visual and auditory cues encourage seabird colonization, and translocation, which involves moving young birds to safer breeding grounds where they will return as breeding adults. Social attraction is favored for species with lower natal fidelity, while translocation is reserved for species exhibiting strong site fidelity and lacking nearby colonies.

The purpose of this report is to identify and prioritize seabird species in the USTP and CCE that are vulnerable to climate change, determine which restoration techniques are appropriate for each species, and identify sites where the most vulnerable species could be restored. We evaluated 62 seabird species across both regions and prioritized them based on vulnerability criteria that included population size and trend, projected impact of climate change, and conservation status at multiple geographic scales. We then determined whether social attraction or translocation was the recommended restoration technique based on the species biology and aspects of the restoration sites available.

The species at highest risk from climate change differed between the regions. In the USTP, procellariform species (albatrosses, petrels, shearwaters, and storm-petrels) dominated the list of at-risk seabirds, due to their strong natal site fidelity, limited geographic ranges, and high proportion of the population nesting on low-lying atolls. In contrast, in the CCE most of the species at greatest risk were alcids and terns, which have lower site fidelity and post-fledging parental care. These differences in species composition between the regions resulted in different recommended restoration methods (i.e., translocation is the USTP vs. social attraction in the CCE).

Site assessments in both regions identified priority sites for potential seabird restoration projects that are safe from projected sea level rise, under some level of conservation protection, had suitable nesting habitat, and where invasive mammals were not present or were controlled. High-priority sites in the USTP include predator-free, higher elevation offshore islets or sites on larger islands with existing predator exclusion fences. In the CCE, the analysis was restricted to federal sites that were within 16 km of the coast and offer safe habitat within seabird foraging ranges.

Collaborative efforts to centralize and standardize seabird population data, particularly within the CCE, along with further research into climate impacts on seabird reproductive success, are crucial for effective conservation planning. By combining targeted restoration actions with a climate-adaptive approach, this report underscores the importance of proactive, science-based conservation planning that can be scaled and adapted to diverse ecological contexts. Ultimately, the prioritization of at-risk seabirds and their habitats within the USTP and CCE represents a crucial step toward building resilience in marine biodiversity and supporting global efforts to protect and restore vulnerable ecosystems.

1. INTRODUCTION

Seabirds include some of the most vulnerable avian species globally, facing a range of natural and human-induced threats that have led to population declines worldwide (Dias et al. 2019). As the only group of birds that depend entirely on marine and coastal ecosystems, seabirds play a critical role in oceanic and coastal biodiversity. They serve as indicators of marine health and are integral to the nutrient cycles of their environments (Piatt e al. 2007). The United States of America (USA) is a global hotspot for seabirds and is home to 149 out of the world's 368 seabird species (Birdlife International). The high species diversity is a function of the country and its territories spanning multiple ocean basins and a wide range of latitudes and habitats from the tropics to the arctic. In the United States, two regions stand out for their significance in supporting diverse seabird populations: the California Current Ecosystem (CCE) and the U.S. Tropical Pacific (USTP). Together, these regions encompass a range of habitats that support an exceptional diversity of seabird species, each with unique ecological roles and conservation needs.

The CCE seabird community consists of over 75 species of breeding and migratory seabirds, the composition of which changes seasonally (USFWS 2005). This community includes three major groups: breeding residents that are present year-round (29 species), nonbreeding visitors that reside in the ecosystem for several months during their nonbreeding season, and migratory species that transit through the region during spring and fall. Geographically, the CCE is large and complex, spanning three states- California, Oregon and Washington. In the south, the ecosystem is composed mostly of species that prefer sub-tropical habitats, whereas sub-arctic species dominate in the north. All species rely to a certain extent on the Humbolt Current, which runs from north to south down the west coast of North America, and on the strong, productive upwelling that is characteristic of the region (Ainley and Hyrenbach 2010, Sydeman 2012). There is substantial intra-annual variability in ecosystem dynamics, with seasonal pulses in productivity along a latitudinal gradient from south to north (generally earlier in the south, later in the north (Chavez et al. 2003; Schwing et al. 2006)). Understanding current and future effects of climate variability and climate change on the CCE is therefore of great interest for the conservation of the seabird species that rely on that system.

The USTP is a globally important area for tropical seabirds, with tens of millions of individuals of at least 32 species breeding in five geographic regions: 1) the Main Hawaiian Islands (MHI), encompassing the larger islands from Hawaii west to Niihau, and including the offshore islets that are geologically associated with each larger island; 2) the Northwestern Hawaiian Islands (NWHI) from Nihoa west to Kure Atoll; 3) the Mariana Islands (MI), including Guam and the Commonwealth of the Northern Mariana Islands (CNMI); 4) American Samoa (AS), including Rose Atoll and Swains Island; and 5) the Pacific Remote Islands Marine National Monument (Remotes), which includes Palmyra Atoll, Kingman Reef, Wake, Johnston, Jarvis, Howland, and Baker (Figure 1) as outlined in Young and VanderWerf (2023). Collectively, the islands in the USTP support the largest tropical seabird colonies in the world (Naughton et al. 2005). Seabird breeding habitat within this region is highly variable, ranging from low-lying atolls that are vulnerable to sea level rise, to high elevation montane areas on larger islands. The 32 seabird species breeding in the USTP vary in their distribution, with some species being widespread and occurring on most islands in all regions (e.g., Wedge-tailed Shearwater

(*Ardenna pacifica*), Red-tailed Tropicbird (*Phaethon rubricauda*), and Black Noddy (*Anous minutus*), and other species being restricted to just one or a few islands in one region (e.g., Short-tailed Albatross (*Phoebastria albatrus*), Tahiti Petrel (*Pseudobulweria rostrata*), Tropical Shearwater (*Puffinus bailloni*), and Polynesian Storm-petrel (*Nesofregetta fuliginosa*).

Both the USTP and CCE are exposed to unique and increasingly severe threats due to climate change and anthropogenic pressures. Rising sea levels pose a particular challenge for the USTP, where many nesting sites are located on low-lying islands vulnerable to inundation. This threat is being exacerbated by more frequent and intense storm surges, which can destroy nesting areas, reduce breeding success, and limit available habitat for subsequent generations (Reynolds et al. 2015). Additionally, invasive species such as rats, cats, and mongoose pose a persistent threat to seabirds in the USTP, predating on eggs, chicks, and adult birds. Invasive species have devastated many seabird populations in island ecosystems, where native species have evolved in predator-free environments and lack the defenses needed to cope with introduced predators (Jones et al. 2016; Spatz et al. 2017). This combination of climate-driven habitat loss and biological threats creates an urgent need for targeted conservation measures in the USTP.

In the CCE, seabirds contend with a different suite of threats owing to the differences in latitude (mostly temperate), higher elevations, and, for some species, natural co-existence with native mammalian predators. Moreso than in the USTP, offshore development, such as wind farms and oil rigs, pose collision risks and habitat disturbance, potentially disrupting foraging and migratory routes (Furness et al. 2012, Croll et al. 2022). Human activities near coastal habitats, including fishing and recreational disturbances, add further stress to breeding colonies. Climate change compounds these pressures by altering ocean temperatures and food availability in this cold-water upwelling system; warmer waters can disrupt the abundance and distribution of prey species, affecting seabird foraging success and reproductive outcomes (Ainley and Hyrenbach 2010; Sydeman et al. 2012). Marine heatwaves, increasingly frequent in the CCE, can lead to shifts in prey distributions that force seabirds to travel further from nesting sites to find food, thereby reducing reproductive success and chick survival (Hobday et al. 2016; Sydeman et al. 2021). Collectively, these threats create a complex conservation landscape in the CCE, where the impacts of climate change intersect with human activity to create a different set of challenges for seabird conservation when compared to the USTP. As a result of these suites of threats seabirds in both regions experience, concerted efforts are underway to not only mitigate these threats at the source, but also recognizing that in some cases, colony relocation and/or restoration may be necessary to support the long-term survival of some species in new locations.

Efforts have accelerated recently to restore seabird populations, and, in addition to habitat management and predator removal, frequently have involved more direct techniques, primarily social attraction and translocation (Jones and Kress 2012, Zhou et al. 2017, Spatz et al. 2023, VanderWerf et al. 2023). These efforts have helped seabirds reclaim some historical nesting areas and find safer nesting places in the face of increasing anthropogenic threats. The effectiveness of social attraction and translocation for restoring or creating seabird breeding colonies depends on multiple factors, including the natural history of the species involved, the biotic and abiotic characteristics of the restoration site, and proximity to the nearest existing colony (Jones and Kress 2012, Buxton et al. 2014, VanderWerf et al. 2019, VanderWerf et al.

2023). Social attraction involves attracting seabirds to a site with visual, auditory, and occasionally olfactory lures and is more effective in colonial species with weak natal philopatry, post-fledging parental care, and where existing colonies of the target species are nearby (Buxton et al. 2014). Translocation involves physically moving birds from one location to another, usually when they are chicks, and caring for them until they fledge, and is necessary more often in species with strong natal philopatry, limited or no post-fledging care, and where there are no nearby colonies (Jones and Kress 2012, VanderWerf et al. 2023). Seabird restoration is a long-term process; it often takes years to begin achieving desired results and thus it is crucial to start the process as soon as a threat or need is identified. However, the success of these methods depends on factors such as species' natural history, the suitability of restoration sites, and proximity to existing colonies.

With limited resources and varying degrees of vulnerability across species and habitats, conservation practitioners require a systematic approach to identify and prioritize species and sites most in need of intervention and to maximize the chances of success based on the restoration method chosen. Two previous prioritizations exist for this region: a course high level one done by Young et al. in 2012 for all seabirds in the Western USA, and a second by Young and VanderWerf (2023) that focused exclusively on the USTP. Even within the span of one year, data has been made available that changes the outcome of previous efforts, especially when both regions are grouped into a single document to better reflect geopolitical and ecological boundaries of the species in question.

The purposes of this document are to: 1) prioritize seabird species in the CCE and USTP using the same criteria as Young and VanderWerf 2023; and 2) prioritize sites where restoration could be undertaken for the species in that region. By developing a standardized prioritization framework, this report provides a strategic tool for seabird conservation practitioners, guiding immediate and long-term actions in response to climate-related threats. This study aims to complement existing best practices for seabird restoration, offering a set of recommendations that enhance conservation efforts at both regional and ecosystem-wide scales. Through this framework, managers can better allocate resources to protect seabird populations, mitigate population declines, and secure long-term resilience against mounting climate threats.

2. METHODS

We included all 62 seabird species known to nest in the USTP and US-CCE in this study, of which 31 nested in the USTP, 29 species nested in the CCE, and two species were shared by both regions (Table 1). The list of species nesting within the USTP followed that used by Young and VanderWerf (2023). For the CCE, we started with the species covered in the USFWS Seabird Conservation Plan (2005) and checked regional resources (e.g., USFWS regional breeding seabird websites) and other reports and published articles to verify current breeding distributions (e.g., Kelsey et al. 2018, Vanderwerf et al. 2023). Taxonomy largely followed BirdLife International 2023 standards, but we made a few additions. For example, we distinguished the California Least Tern from the more widely distributed Least Tern. We also updated the taxonomy of the Cocos Booby (*Sula brewsteri*), which was split recently from the Brown Booby (*S. leucogaster*; Chesser et al. 2024) and occurs primarily in the CCE. This species' range is expanding westward and it now nests on several islands in the USTP in small numbers

(VanderWerf et al. 2008, 2023). Only two species occurred as breeding species in both regions, Cocos Booby and Laysan Albatross (*Phoebastria immutabilis*). The Laysan Albatross nests primarily in the Hawaiian Islands, but there is a growing colony on Guadalupe Island, Mexico, at the southern end of the CCE (Hernández-Montoya et al. 2014, Henry et al. 2021).

2.1. Species prioritization. We used six criteria to evaluate the extinction risk and vulnerability to climate change of each species. Two of the six criteria were related to the distribution and abundance of the species, three criteria were based on existing conservation assessments at different geographic scales, and one criterion was based on severity of the impact of climate change to each species. We assigned a numerical score ranging from 1 to 3, 4, or 5 to each species for each criterion, with higher scores indicating greater extinction risk or higher vulnerability. We then summed the scores of all criteria to obtain an overall score, which is an indication of vulnerability and conservation need. Below we describe each criterion, including justification for its inclusion, the scale, data source(s), and any other information important for understanding that criterion and how it was used.

Three of the criteria were based on existing conservation status assessments: the International Union for the Conservation of Nature (IUCN) status, status under the U.S. Endangered Species Act (ESA), and state or territory status. We used three criteria because the status of some species differed among them, reflecting variation in global, national, and regional importance or differences in taxonomy, and because the methods for determining the status of a species in each system were somewhat different. All three of these assessments included various aspects of climate change in determining an overall threat status. In most cases the global, national, and regional status were similar, but in some cases they were quite different. Harris et al. (2012) found that 40.3% of U.S. birds considered imperiled by the IUCN are not listed under the ESA, and usually only species with higher IUCN threat levels are recognized by the ESA.

IUCN (global) status. We used global population status information directly from the latest version of the IUCN redlist (https://www.iucnredlist.org accessed 04/23/2024), and we scored each species on a scale from 1 to 5 according to its IUCN category: Least Concern (1), Near Threatened (2); Vulnerable (3); Endangered (4); and Critically Endangered (5).

U.S. Endangered Species Act status. We scored each species on a scale from 1 to 4 according to its ESA status: Not listed (1); Species of conservation concern (2); Threatened (3); and Endangered (4). A list of species of conservation concern is maintained by the U.S. Fish and Wildlife Service (USFWS 2021). Although these species are not actually listed and are not afforded any legal protection because of this designation, their inclusion in this category indicates there is reason for concern about their status. They are sometimes regarded as species that might warrant listing in the future (USFWS 2021).

State status. For USTP species, we used scores already assigned by Young and VanderWerf (2023), which were based primarily on the proportion of the global population breeding in the U.S. Tropical Pacific. We scored proportion of the population within the USTP on a scale of 1 to 5 based as follows: (1): <10%; (2): 10-30%; (3): 30-70%; (4): 71-90%; (5): >90%. For the CCE species, we used a score assigned by one or more state documents. For California, we used the California Endangered Species Act (CDFW ESA 2015) and CDFW Species of Special Concern list (SSC, Shuford and Gardali 2008). For Oregon and Washington, we used threat statuses consolidated in Kelsey et al. (2018). In cases where the status differed among states, we used the highest score from any state.

Climate change vulnerability. This criterion was intended to be a broad indication of overall vulnerability to climate change based on both adaptive capacty of seabirds to changing climate and direct and indirect exposure to climate-related impacts. These impacts included: inundation of breeding colonies by sea level rise and increasing storm surge; changes in prey abundance or availability caused by changes in ocean temperature or circulation patterns; marine heat waves and overheating from temperature extremes at breeding sites; and effects of changing rainfall patterns on vegetation and erosion in breeding areas. For USTP species, we started with scores assigned by Young and VanderWerf (2023), which were based on the proportion of the population that nests on islands <5m in elevation that are expected to be inundated over the next few decades. For some species we assigned a higher score if there was evidence that other aspects of climate change are also expected to affect the species. For example, changing rainfall patterns that promote invasion by alien plant species are expected to degrade habitat quality for the Hawaiian Petrel (*Pterodroma sandwichensis*) and Newell's Shearwater (*Puffinus auricularis newelli*), so we assigned a higher score for those species.

For the CCE species, we calculated an overall climate vulnerability score by averaging four individual scores, including one score that reflected the size of the species range, and three scores from references that assessed climate vulnerability of CCE seabirds (Young et al. 2012, Gardali et al. 2012, Sydeman et al. 2021). We then rounded the resulting average to the nearest whole number. For the species range score, we assigned a value from 1-5 using the following definitions: 1 = Broad range in the Pacific or world-wide; 2 = Broad range in the eastern Pacific; 3 = Range encompasses most or all of the CCE; 4 = Occurs only in part of the CCE; 5 = Confined to a small range or a few breeding locations only within the CCE.

Each of the three climate vulnerability references used multiple factors to assess observed and anticipated effects of climate change on species. Young et al. (2012) assigned scores to each species on a scale from 0 (low) to 2 (high), which we converted to a scale from 1-5 based on information contained in that report about the nature and severity of the threat to each species. Gardali et al. (2012) prioritized species from 1 (highest) to 3 (lowest), which we converted to a scale from 1-5 (1 in Gardali et al. = 5 in our system, 2 in Gardali et al. = 3 in our system, 3 in Gardali et al. = 1 in our system). Sydeman et al. (2021) did not assign scores, but we used information in the paper in the following way: If there was a statistically significant negative impact to a species, we assigned a score of a 5; if the authors suggested there was a negative climate impact but it was not statistically significant or was not tested, we assigned a score of 3; if climate impacts were not significant or were significantly positive, we assigned a score of 1.

Population size. For global population size, we used data provided in the latest version of the IUCN redlist (https://www.iucnredlist.org accessed 04/23/2024), with a few exceptions that warrant explanation. For some species the population size estimate was a range; in such cases we used the average of the high and low values. For species in which the population size was given as unknown by IUCN we obtained information from the following sources: Southey and Frost (2013, for Bulwer's Petrel); Brooke (2004, for Herald Petrel and Christmas Shearwater); Partners in Flight (2021, for Masked Booby, Brown Booby, Red-footed Booby, and Least Tern); and Kushlan et al. (2002, for Elegant Tern). We scored population size on a scale of 1 to 5 based on the number of individuals: (1): >100,000; (2): 50,000-100,000; (3): 10,000-50,000; (4): 1,000-10,000; (5): <1,000. If the population size could not be determined from the literature but was listed as "large or very large" by IUCN, we assigned the species a score of 1.

Population trend. Similar to population size, for global population trend we used data provided in the latest version of the IUCN redlist (https://www.iucnredlist.org accessed 04/23/2024), with a few exceptions. We considered the population trend of Black-footed Albatross to be stable (rather than increasing as in IUCN), because most recent information indicates the species is stable or possibly increasing (Arata et al. 2009, USFWS unpub data). We scored population trend on a scale of 1 to 3 as follows: (1): increasing; (2): stable; (3): decreasing. Species with an unknown population trend were assigned a value of 2.

To calculate the proportion of the global population nesting in the USTP, we used information about regional abundance from several sources. For species occurring in the Hawaiian Islands, we obtained population size estimates primarily from Pyle and Pyle (2017), which contains an appendix of seabird populations by island that were provided by researchers and managers familiar with each island. For some species and locations we supplemented data in Pyle and Pyle (2017) with more recent data from personal observations and other sources, including Bonin Petrels on O`ahu (PRC unpubl. data), Wedge-tailed Shearwaters on Kaua`i and O`ahu (Felis et al. 2019, PRC unpubl. data), Red-footed Boobies on Kaua`i (Felis et al. 2019), Red-tailed Tropicbirds on Lehua Islet, Kaua`i, and O`ahu (Felis et al. 2019, Raine et al. 2021, Vanderwerf 2021), White Terns on O`ahu (VanderWerf and Downs 2018), and Least Terns on Oahu (Harmon et al. 2021). Hawaiian Petrels and Newell's Shearwaters have been detected regularly on O`ahu recently (Young et al. 2019), but because no nests have been found yet they were not counted as breeding on O`ahu for the purposes of this study.

For islands in the Pacific Remote Islands Marine National Monument, we obtained information from these sources: Palmyra (Wegmann and Kropidlowski unpubl. data), Baker, Howland, and Jarvis (Rauzon et al. 2011), and Johnston (Schreiber 2003), with more recent data from USFWS (2021) for boobies, frigatebirds, and tropicbirds.

In the Marianas, we obtained data for some islands from Reichel (1991), but we used more recent data from the following islands and sources: Guam; Rota, Commonwealth of the Northern Marianas, (Commonwealth of the Northern Marianas 2020); Farallon de Medinilla (FDM; Liske-Clark et al. 2016); Tinian, Aguiguan, and Naftan Rock (Amidon et al. 2014); Guguan (Liske-Clark et al. 2016). We also filled in data gaps for a few species with estimates from Stinson (1995) and for Maug from Eldredge et al. (1977). Camp et al. (2014) analyzed long-term helicopter survey data of the three booby species from FDM but did not provide population estimates. If population estimates for a species differed among sources, we used the more recent estimate unless there was evidence that the variation was related to breeding seasonality, in which case we used the estimate during the breeding season.

In American Samoa, we obtained data from the following sources: Swains Atoll (Titmus et al. 2016), Tutuila and Ta'u (O'Connor and Rauzon 2004, Titmus 2017, PRC unpubl. data).

2.2. Evaluation of restoration sites and potential source sites. We attempted to identify suitable locations that could serve as restoration sites or sources for translocation of high priority seabird conservation actions in both the USTP and CCE.

2.2.1. U.S. Tropical Pacific Sites. In the USTP, we assessed 86 locations in all five regions of the USTP as being suitable or unsuitable for seabird restoration based on several factors, including elevation, presence of predators, ability to exclude or eradicate predators, and other anthropogenic risks. We considered a site to be suitable for restoration if: 1) it was not at risk of inundation; 2) predators and other anthropogenic threats were absent, had been eliminated or effectively managed, or could be effectively managed in the long-term; 3) there were no serious logistical constraints. We considered a colony to be a suitable source for translocation if it was: 1) at risk of inundation from sea level rise and storm surge such that the long-term persistence of the colony was in doubt; 2) experiencing predation by invasive species that was difficult or impractical to manage; and 3) large enough to sustain removal of the desired number of individuals for several years. If there was no suitable source for a species within the USTP, we identified the closest suitable location outside of the USTP. More details about methods used to identify suitable restoration sites can be found in Young and VanderWerf (2023).

Islands and atolls where the majority of the island was < 5m ASL we generally did not consider to be suitable restoration sites (Nunn et al. 2016), but in certain cases we did consider low islands for restoration if an action was urgently needed to mitigate another threat and no other suitable sites were available in the near-term, with the realization that the island would serve primarily as a temporary stepping-stone that would facilitate eventual restoration at another location. For example, Palmyra Atoll is vulnerable to inundation in the long-term, but rats were eradicated from the atoll recently (Wegmann et al. 2012), and it could serve as a valuable location in which to establish colonies of some of the highest priority species, and could serve as a source for future efforts on other islands.

2.2.2. California Current Ecosystem Sites. For the CCE, due to the greater geographic scope and larger number of potentially suitable sites compared to the USTP, we evaluated only sites that were under perpetual federal protection and which were within 16 km (10 miles) of the coast as potential seabird restoration sites. This mainly included national wildlife refuges and national parks and monuments. This yielded a total of 32 sites for evaluation as seabird restoration sites. It would be useful to extend this analysis in the future to sites that are owned or managed by state, regional, or private entities.

As with the USTP, we evaluated whether each site was suitable for seabird restoration using a series of criteria, which included: island vs. mainland, presence of invasive predators, and presence of the following habitat characteristics needed by the various species for successful nesting: soil, sand, vegetation, old growth forests, and river/estuary habitats. For the species identified as high priority in the seabird prioritization, we documented the top five habitat characteristics necessary for breeding, based on Cornell's Birds of the World online database (2024). We then matched the species-specific breeding habitat requirements against the habitat variables collected for each potential restoration site, which provided us with a list of potentially suitable restoration sites for each priority species. Next, for each site per species, we determined the following information: whether the site was within or outside the species current breeding range and foraging ranges, whether the species was already breeding at the site, and, if so, the approximate breeding colony size, and if any suitable but unoccupied habitat likely still existed; and the nearest largest colony to the property that may serve as a source for social attraction. For each site, we also noted the presence or absence of invasive predators.

Using this information, we scored each site for each species on a scale from 0 (lowest priority) to 4 (highest priority), using the definitions shown in Table 1.

Table 1. Scoring definitions for prioritizing restoration sites in the CCE.

SCORE	Time frame	Definition
4	Suitable now	habitat is suitable, site is within species current foraging range, predators not present or managed, and the species is not currently breeding anywhere within the site.
3	Could be made suitable in ~5-10 years	habitat is suitable, site is within current foraging range, species may be present but not all suitable habitat is occupied, but predators or other threats require management.
2	Might be suitable in 10-20 years	Habitat is suitable, predators absent or managed, but site is outside species current foraging range. Could become suitable for social attraction if species range expands, translocations possible.
1	20+ years	Habitat not currently suitable, site is far outside current breeding and/or foraging range, and predators present or unknown.
0	Not needed	Species is already breeding in medium to large numbers and seems stable, augmentation not needed.

More detailed information about criteria to consider in selecting restoration sites for a particular project and sources of birds for translocation are provided in the best practices document (VanderWerf and Young 2024). If a suitable source location was not available for a species within the region, we attempted to identify the closest and most suitable location outside of the region.

2.3. Determination of recommended restoration techniques. To determine which restoration technique (social attraction or translocation combined with social attraction) was likely to be more effective, we considered whether each species exhibits natal philopatry and post-fledging care, and the relative location of potential source and restoration sites. If a species does not exhibit high natal philopatry, then the chances of a translocation succeeding are low. Only species with high natal philopatry and no post-fledging parental care were considered suitable candidates for translocation; any species that exhibit post-fledging care were excluded from translocation consideration. For more detailed information about selecting the restoration method for different seabird species, refer to the best practices document (VanderWerf and Young 2024).

3. RESULTS

3.1 Species Prioritization. When all 62 species were evaluated and ranked across both regions (Appendix 1), the species at highest risk were split almost equally between regions (11/20 in USTP, and 8/20 in the CCE, one shared by both regions; Tables 2 and 3). However, there were differences in the highest-ranking species between the two regions. In the USTP, all but two of the highest ranked species were the order Procellariformes (albatrosses, petrels, shearwaters, and storm-petrels). In contrast, in the CCE there was more taxonomic diversity, with six alcid species (murrelets, auklets, and puffins), two Procellariforms, and two terns. More detailed information about species in each region is provided below.

3.1.1. U.S. Tropical Pacific Species. The 12 species in the USTP most at-risk from climate change (multiple species were tied for rankings) are listed by rank in Table 2 below.

Table 2. USTP seabird species ranked by climate change vulnerability, with recommended restoration method(s) based on life history and colony locations.

Species	**USTP Rank**	**Natal philopatry?**	**post-fledging care?**	**Nearby colonies?**	**Translocation, social attraction, or both**
Hawaiian Petrel	1	yes	no	yes	Both
Newell's Shearwater	1	yes	no	yes	Both
Polynesian Storm-petrel	3	yes	no	no	Both
Phoenix Petrel	4	yes	no	no	Both
Black-footed Albatross	5	yes	no	yes	Both
Laysan Albatross	5	yes	no	yes	Both
Bonin Petrel	7	yes	no	no	Both
Red-tailed Tropicbird	7	yes	no	yes	Both?
Band-rumped Storm-petrel	9	yes	no	yes	SA
Masked Booby	10	no	yes	yes	SA
Short-tailed Albatross	10	yes	no	no	Both
Tristram's Storm-petrel	10	yes	no	no	Both

The prioritization exercise revealed several noteworthy patterns. Only five of 31 seabird species that nest in the USTP are considered imperiled by the IUCN (status vulnerable or worse; Short-tailed Albatross, Hawaiian Petrel, Phoenix Petrel, Newell's Shearwater, Polynesian Storm-petrel), and only four are listed under the U.S. ESA (Short-tailed Albatross, Hawaiian Petrel, Newell's Shearwater and Band-rumped Storm-petrel), with 16 more considered species of concern. However, the majority, 20 species, were decreasing in abundance and only one species was increasing in abundance (Short-tailed Albatross). For Band-rumped Storm-petrel, the IUCN score was lower than the ESA and State scores because the listed taxon includes only the Hawaii population of the species, and the IUCN does not consider subspecies or populations and evaluates the species as a whole.

Taxonomically, Procellariforms (albatrosses, petrels, shearwaters, and storm-petrels) had generally higher scores, indicating greater extinction risk, with 10 of the top 12 most at-risk species in this order (Table 2). Five species occurred primarily within the USTP, with >90% of their global populations in this region, with another four species having >70% of their global populations in the USTP, while 16 species occurred primarily (>90%) outside the USTP. About one-third of the USTP species (10) nest primarily (>70%) in locations < 5 m ASL, indicating their vulnerability to climate change.

Of the top 12 ranked species, 11 exhibit strong natal philopatry and thus would be suitable for translocation (Table 2). For seven of the 12 species, there are existing colonies close enough to suitable restoration sites that social attraction might be effective; for the other four species, social attraction is unlikely to work because there are no colonies close enough to suitable restoration sites, indicating translocation would be necessary to create colonies.

3.1.2. California Current Ecosystem Species (Table 3). The 10 seabird species in the CCE most at-risk from climate change and listed by rank in Table 3 below.

Table 3. CCE seabird species ranked by climate change vulnerability, with recommended restoration method(s) based on life history and colony locations.

Species	**USTP Rank**	**Natal philopatry?**	**post-fledging care?**	**Nearby colonies?**	**Translocation, social attraction, or both**
Marbled Murrelet	1	no	yes	Yes	SA
Ashy Storm-petrel	1	yes	no	Yes	Both
Least Tern California	1	no	yes	Yes	SA
Guadalupe Murrelet	4	no	yes	Yes	SA
Scripps's Murrelet	5	no	yes	Yes	SA
Laysan Albatross	6	yes	no	Yes	Both
Craveri's Murrelet	7	no	yes	Yes	SA
Cassin's Auklet	8	yes	no	Yes	Both?
Tufted Puffin	9	no	no	Yes	Both
Elegant Tern	10	no	yes	Yes	SA

Only two of the CCE species are listed under the Endangered Species Act, Marbled Murrelet and California Least Tern. The Ashy Storm-Petrel was considered for listing under the ESA in 2009 and 2012 but was not listed (USFWS 2013). It is considered a Species of Special Concern in California and is listed as Endangered by the International Union for Conservation of Nature. Six of the 10 CCE species exhibit extended periods of post-fledging parental care, including all four murrelets and both terns, and thus social attraction is the only suitable restoration method for these species.

3.2 Restoration Site Prioritization.

3.2.1. U.S. Tropical Pacific Sites. Of the 86 sites we evaluated in the USTP, 16 were suitable restoration sites for the highest priority species (Table 4 arranged by species, Appendix 2 arranged by site). Twelve sites were suitable for restoration and four more sites will become suitable for restoration pending completion of planned predator exclusion fences or predator removal (also see Young and VanderWerf 2024). For the Band-rumped Storm-petrel, only a few active nests have been found and the known colonies are very small (Galase 2019, Antaky et al. 2019), so they could not withstand removal of chicks for translocation. For three of the priority species, Short-tailed Albatrosses, Phoenix Petrel, and Polynesian Storm-petrel, no suitable sources exist within the USTP, so sources for translocation were identified elsewhere. For all three albatross species, suitable restoration sites also were identified in the Eastern Pacific (California Channel Islands and islands off Mexico; Table 5).

The majority of restoration sites for seabirds in the USTP identified were in the Main Hawaiian Islands. This is a function of two factors: first, numerous predator-free offshore islets exist in the MHI, and second, the majority of predator exclusion fences that have been built to create predator-free 'mainland islands' are in the MHI (Young and VanderWerf 2024). Predator eradications and predator exclusion fencing on high islands in the Marianas and American Samoa would increase the potential to use those regions for restoration and should be considered a high priority management activity to increase the geographic scope of seabird restoration in the USTP.

Table 4. Sites in the USTP that are suitable for restoration of species most vulnerable to climate change. MHI = Main Hawaiian Islands.

Species	USTP Rank	Translocation sources	Restoration sites
Hawaiian Petrel	1	Lanai, Kauai	Predator fences and offshore islets in MHI
Newell's Shearwater	1	Kauai	Predator fences and offshore islets in MHI
Polynesian Storm-petrel	3	Kiribati	Palmyra, coastal predator fences and offshore islets in MHI
Phoenix Petrel	4	Kiribati	Palmyra, coastal predator fences and offshore islets in MHI
Black-footed Albatross	5	Midway, Tern Island	Mexican islands, California Channel Islands, coastal predator fences in MHI
Laysan Albatross	5	PMRF, Midway, Tern Island	California Channel Islands, coastal predator fences in MHI
Bonin Petrel	7	Midway	Coastal predator fences and offshore islets in MHI
Red-tailed Tropicbird	7	NA	Coastal predator fences and offshore islets in MHI
Band-rumped Storm-Petrel	9	None	Lehua Islet, predator fences and offshore Islets in MHI
Masked Booby	10	NA	Coastal predator fences and offshore islets in MHI
Short-tailed Albatross	10	Torishima, Japan	California Channel Islands, coastal predator fences in MHI, Guadalupe Is.
Tristram's Storm-petrel	10	Tern Island	Lehua Islet, predator fences and offshore Islets in MHI

3.2.2. California Current Ecosystem Sites. Of the 32 sites we evaluated, 30 had suitable habitat characteristics for priority seabirds and were evaluated for restoration potential, including 15 sites in California, 6 in Oregon, and 9 in Washington (Appendix 3). Of these sites, 5 received the highest score (4) for suitability to protect nine priority species now (Table 5): California: Castle Rock NWR and Channel Islands NP in California; Oregon Islands NWR and Three Arch Rock NWR in Oregon; and: San Juan Islands NWR in Washington. Twenty-two sites received a score of 3, indicating the potential availability of suitable habitat in the future.

Table 5. Highest-ranked Federal sites in the California Current Ecosystem that are suitable for restoration of species most vulnerable to climate change. NP = National Park, NWR = National Wildlife Refuge. For a list of all sites, see Appendix 3.

Species	State	Location name	Score	Justification
Ashy Storm-petrel	CA	Channel Islands National Park	3	Colonies exist on some islands but more suitable areas available for restoration
	CA	Point Reyes National Seashore	3	suitable sites still available within on mainland and on offshore rocks
Least Tern	CA	Antioch Dunes NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	CA	Don Edwards San Francisco Bay NWR	3	breeding nearby at Edan Landing
	CA	Guadalupe-Nipomo Dunes NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	CA	Marin Islands NWR	3	
	CA	Point Reyes National Seashore	3	mainland site where suitable habitat can be secured with restoration interventions
	CA	Salinas River NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	CA	San Diego Bay NWR	3	breeding at South San Diego unit and occurs in the Sweetwater Marsh unit
	CA	San Pablo Bay NWR	3	mainland site where suitable habitat can be secured with restoration interventions
Ashy Storm-petrel	CA	Castle Rock NWR	4	predator free island within foraging range
Marbled Murrelet	WA	San Juan Islands NWR	4	suitable habitat available on invasive predator free islands
Guadalupe Murrelet	CA	Channel Islands NP	3	small colonies on some islands but more suitable areas available for restoration
	CA	Farallon NWR	3	suitable habitat can be secured with restoration interventions
	CA	Point Reyes National Seashore	3	suitable habitat can be secured with restoration interventions
	CA	Castle Rock NWR	4	predator free island within foraging range, outside breeding range
Scripps's Murrelet	CA	Castle Rock NWR	4	predator free island within foraging range
	OR	Oregon Islands NWR	4	predator free island within foraging range

	OR	Three Arch Rocks NWR	4	predator free island within foraging range
Laysan Albatross	CA	Point Reyes National Seashore	3	suitable habitat can be secured with restoration interventions
	CA	Channel Islands NP	4	suitable habitat available on invasive predator free islands
Craveri's Murrelet	CA	Channel Islands NP	3	suitable habitat is available
	CA	Farallon NWR	3	suitable habitat can be secured with restoration interventions
	CA	Point Reyes National Seashore	3	suitable habitat can be secured with restoration interventions
Cassin's Auklet	CA	Cabrillo NM	3	mainland site where suitable habitat can be secured with restoration interventions
	CA	Point Reyes National Seashore	3	suitable sites available on mianland and on offshore rocks
	OR	Cape Meares NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	OR	Oregon Islands NWR	3	declining colonies in refuge
	OR	Three Arch Rocks NWR	4	unclear if breeding at this site; either way suitable habitat is likely still available
	WA	Dungeness NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	WA	Olympic NP	3	mainland site where suitable habitat can be secured with restoration interventions
	WA	Protection Island NWR	3	potential suitable habitat; within foraging range but not breeding range
	WA	San Juan Island NHP	3	large island site where suitable habitat can be secured with restoration interventions
	WA	San Juan Islands NWR	3	suitable sites available within the refuge and on offshore rocks
Tufted Puffin	CA	Point Reyes National Seashore	3	suitable sites available within the park and on offshore rocks
	OR	Cape Meares NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	OR	Oregon Islands National Wildlife Refuge	3	numbers have declined across the refuge; suitable habitat is available
	OR	Three Arch Rocks NWR	4	predator free island within foragingand breeding range
	WA	Dungeness NWR	3	mainland site where suitable habitat can be secured with restoration interventions
	WA	Olympic NP	3	mainland site where suitable habitat can be secured with restoration interventions
	WA	San Juan Island NHP	3	suitable habitat can be secured with restoration interventions
	WA	San Juan Islands NWR	3	suitable sites available within the refuge and on offshore rocks
	WA	Washington Islands NWR	3	colonies exist on some islands, unocuupied suitable habitat likely remains

Elegant Tern	CA	Marin Islands NWR	3	suitable habitat can be secured with restoration interventions
	CA	Point Reyes National Seashore	3	suitable habitat can be secured with restoration interventions
	CA	Salinas River NWR	3	suitable habitat can be secured with restoration interventions
	CA	San Diego Bay NWR	3	likely suitable habitat is still available for species
	CA	Seal Beach NWR	3	suitable habitat can be secured with restoration interventions
	CA	Tijuana Slough NWR	3	breeding near site in small numbers; common visitor to refuge
	CA	Channel Islands NP	4	suitable habitat is available

4. DISCUSSION

This study offers a preliminary analysis for understanding seabird climate-change vulnerability in the U.S. Tropical Pacific (USTP) and California Current Ecosystem (CCE) by prioritizing at-risk species and suitable sites for restoration efforts. By integrating species vulnerability scores with restoration site assessments, the study identifies high-priority areas for conservation actions and restoration strategies tailored to the specific needs of seabird populations across these regions as outlined in tables 4 and 5. It also serves as a living document that can be updated as species needs change and/or more restoration sites become available.

4.1 Regional Differences

The aim of our study's differentiation between CCE and USTP species is meant to help guide with the deployment of resources where they will have the most impact while also ensuring that each region's unique ecological context informs restoration methods. The regional variability in vulnerability criteria also underscores the need for an adaptable conservation framework that can accommodate changes in threat levels over time. For instance, certain CCE seabird species that are currently stable may experience rapid declines if new offshore developments are introduced. Similarly, ongoing climate change may exacerbate threats in the USTP, necessitating continuous reassessment of prioritization criteria and restoration recommendations. By incorporating climate projections and adaptive management principles into seabird conservation strategies, this framework can support dynamic, region-specific approaches that are resilient to ecological and environmental shifts

While both regions contained close to equal numbers of high priority species when pooled, our analysis indicated that there were taxonomic and habitat-based patterns that differed between the regions. The greatest threats to breeding seabirds in the USTP were inundation of breeding colonies caused by sea level rise and invasive non-native predators. All species within the USTP breed on oceanic islands that historically did not have mammalian predators, in contrast to many species that breed on continental locations in the CCE that contain native mammals. Fortunately, significant actions have already been taken in recent decades to eliminate or reduce the threat of invasive species across the region (Jones et al. 2016 Spatz et al. 2022). Social attraction and translocation actions have also been used with increasingly frequency more recently to help jump start the creation of new seabird colonies safe from sea level rise (VanderWerf et al. 2019, Spatz et al. 2023, VanderWerf et al. 2023).

The USTP contained a higher proportion of species (10/12 priority species) that could benefit from both social attraction and translocation due to a higher number of Procellariformes nesting in the region. Procellariiformes are known to be among the most threatened groups of seabirds, and all birds (Spatz et al. 2014, Dias et al. 2019), and most of the highest ranked species in this exercise were in this order. One reason that Procellariiformes are especially endangered is their strong natal philopatry, which can limit gene flow among populations and result in evolution of species with limited ranges and local endemism (Greenwood 1980, Friesen 2015, Antaky et al. 2021). In contrast, boobies, tropicbirds, and frigatebirds have lower rates of natal philopatry, with greater movement of individuals among colonies, and species in those groups are more widespread (Steeves et al. 2003, Varela et al. 2020). As a result of the large proporation of Procellariformes among the highest-ranked species, as well as the distance between source and restoration sites, translocation emerged as an essential strategy for these USTP species given their limited adaptive capacity to relocate independently to safer nesting grounds. The ESA and IUCN listing status as well as total populations for USTP priority species were also higher (i.e. they had a higher degree of vulnerability) indicating a higher need for intervention. Indeed, the two species endemic to the region (Newell's Shearwater and Hawaiian Petrel) both have populations that are in rapid decline (Raine et al. 2021) and that will likely approach extinction if some of these actions are not undertaken soon. For those two, and some of the other species in the USTP, this may be the only hope of maintaining healthy populations moving forward.

In contrast, CCE seabirds, such as terns and puffins, show greater habitat flexibility but face distinct threats, including coastal development, prey changes due to disruption of the CCE upwelling system, and human activity near nesting sites. Sydeman et al. (2021) showed that surface-feeding piscivores (many of the alcid species) were more likely to be affected by climate change than other feeding guilds. For CCE species, strategies like social attraction at protected coastal refuges are likely to be more effective than translocation due to these birds' broader nesting ranges, lower site fidelity, and higher degree of post-fledging parental care. The relatively low cost required to implement this intervention provides a straightforward way to jump start conservation interventions for those species listed as priorities.

4.2. Species-Specific Considerations

Although only seven seabird species in the USTP and 10 in the CCE are classified as at risk by the IUCN, and just six are recognized under the U.S. Endangered Species Act (ESA; four in the USTP and two in the CCE), our prioritization analysis reveals that many of the 62 seabird species in the region are under significant threats likely to lead to population declines in the coming years. These populations are generally already decreasing (36/62 species), and the pressures from climate change and invasive predators are expected to intensify without intervention. Immediate conservation measures are advised to support these species and prevent critical situations.

Within the USTP, the Phoenix Petrel and Polynesian Storm-petrel rank among the most endangered seabirds based on biological assessments. However, the Hawaiian Petrel and Newell's Shearwater emerge as top conservation priorities in this analysis due to their restricted global range within the USTP. Sustaining these USTP-endemic species depends entirely on actions taken in the region. In contrast, safeguarding the 16 seabird species that largely inhabit areas outside the USTP, including the Phoenix Petrel and Polynesian Storm-petrel, will primarily require conservation efforts in other regions. For the Band-rumped Storm-petrel, only a few active nests have been found (Galase 2019, Antaky et al. 2019), so there are no suitable sources from which to collect chicks for translocation, and social attraction currently is the only option. For the Red-tailed Tropicbird, although translocation could work in theory because the species has high natal philopatry, there have been few previous translocation attempts with tropicbirds and the outcomes were unknown, so the efficacy of this technique is uncertain for this species (VanderWerf et al. 2024).

The CCE had different species-specific recommendations because 6/10 priority species exhibit extended periods of post-fledging parental care, including all four murrelets and both terns, making social attraction the preferred restoration method. Laysan Albatross were the exception to this and the only species that appeared on the priority list for both regions due to it's large range. For Tufted Puffin, both social attraction and translocation might be effective because both techniques have been used successfully in the Atlantic Puffin (*Fratercula artica*; Kress et al. 1988). For Cassin's Auklet, translocation could be effective in theory but the efficacy is unknown, so social attraction should be attempted first (VanderWerf et al. 2024). There are existing colonies close to suitable restoration sites for all species, so social attraction could be effective for all species. While Tufted Puffin and Cassin's Aucklet were identified as regional priorities, both species had additional breeding sites outside the CCE from Canada to Alaska that would lower the conservation value of CCE specific interventions for these two species. Most of the priority tern and murrelet species could benefit from trialing social attraction at the priority restoration sites given how inexpensive and straightforward this intervention is. In some cases, this could be used to create 'stepping-stone' colonies and progressively move the species' range further north in anticipation of future changes.

4.3. Restoration Site Considerations

The prioritization of restoration sites across the USTP and CCE provides a roadmap for targeted conservation efforts, aligning with the specific nesting and habitat requirements of priority seabird species. Predator-free or predator-managed islands, particularly in the USTP, offer optimal conditions for seabird reestablishment and 16 sites were identified across six islands. Predator exclusion fencing, invasive species eradication, and habitat restoration have proven effective in improving seabird nesting success on several USTP islands (Young and VanderWerf 2024). However, challenges remain, especially in maintaining long-term predator management and addressing logistical constraints associated with remote restoration sites. Despite this, the conservation urgency for intervention within the USTP is higher given the listing status and endemism of several of the species, and planning should start now for those species to ensure projects can proceed given the higher cost of translocation when compared to social attraction alone.

In the CCE, the prioritization of federal refuges and protected coastal areas found several high value locations: Castle Rock and Channel Islands National Park, due to their proximity to key foraging areas and the absence of major predators, and four others that ranked as high. Given the large geographic range of this region, and the low number of sites (only six) that were identified as being shovel ready based on our criteria, sites that ranked as a "3" in this study (i.e. nearly ready) should be an area of focus, particularly if actions such as invasive species removal, which could make the site available for active restoration within the next 10 years. It is well known that invasive species removal is a feasible restoration activity, especially on islands, with high rates of success (Spatz et al. 2022). Predator exclusion fencing on mainland sites is also a feasible action that has been successfully implemented within the USTP (Young and VanderWerf 2024) and could be considered for areas in the CCE that don't have existing populations of native land mammals. Our study's reliance on sites under federal protection offers a limited selection of sites, and extension of this analysis to other sites managed by state or private entities would be valuable, especially if climate-driven changes affect the range and distribution of priority species. Building on collaborative partnerships with state agencies, private landowners, and conservation organizations can help expand the scope of restoration to non-federal lands.

There are many other locations in both regions that support important seabird populations and where other beneficial management actions, such as habitat improvement and predator control, are being conducted or planned, and still more where they are needed that could serve to benefit the seabirds in both regions. Since climate change has been demonstrated to have multiple impacts.

4.4. Data Gaps and Future Opportunities

This study identified key data gaps in understanding climate impacts on seabird populations, particularly in the CCE. For example, a list of US Pacific breeding seabirds was not available and thus we compiled it from various sources. While many individual states maintain colony location and population data, there was not a cohesive data collection strategy or repository for the CCE region even though many of the species span multiple state boundaries and thus their populations must be examined across the region to detect trends. In many cases, it was impossible to obtain current estimates at a state level, or estimate that were obtained were more than 10 years old. Similarly, only a few publications were available assessing the impact of climate change on seabird demographics and productivity, and many of the sources cited were over 20 years old. Thus, not all seabirds within the CCE have been effectively evaluated on climate impacts. While this report provides a preliminary vulnerability assessment, certain areas could benefit from further research to enhance species-specific and site-specific conservation planning. As climate change progresses, such data will become increasingly important in forecasting population trends and understanding species' resilience to environmental shifts. While we were able to supplement our research with data from recent published literature and reports, this was not available for all seabirds at all sites. Standardizing seabird data collection across the USTP and CCE would also facilitate comparative studies and longitudinal analyses, enabling conservationists to monitor trends and adapt strategies more effectively. Collaborative data-sharing platforms among seabird research institutions and conservation organizations could improve access to real-time population data and ecological findings. In addition to enhancing regional conservation capacity, such collaboration could foster international partnerships, particularly for species with migratory patterns that cross national borders.

Finally, integrating traditional ecological knowledge (TEK) from indigenous communities in the USTP and CCE could provide valuable insights into long-term ecological changes and species behavior that may not be captured by scientific data alone as well as identify new restoration locations. Community-based conservation approaches that involve local stakeholders could enhance restoration efforts by aligning them with cultural values and knowledge systems. By incorporating TEK and fostering local stewardship, conservationists can increase the sustainability and cultural relevance of seabird restoration initiatives in the region.

4.5. Conclusions

The findings from this prioritization exercise have implications beyond the USTP and CCE, contributing to a growing body of research focused on climate adaptation for vulnerable species. As climate change continues to reshape marine and coastal ecosystems, conservation efforts that anticipate and address these impacts will be essential to sustaining biodiversity. This framework not only supports the conservation of Pacific seabird populations but also serves as a model for other regions facing similar challenges. By combining targeted restoration actions with a climate-adaptive approach, this report underscores the importance of proactive, science-based conservation planning that can be scaled and adapted to diverse ecological contexts. Ultimately, the prioritization of at-risk seabirds and their habitats within the USTP and CCE represents a crucial step toward building resilience in marine biodiversity and supporting global efforts to protect and restore vulnerable ecosystems.

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