Sanderling (*Calidris alba*)

Climate Change Vulnerability Assessment for the Golden Gate Biosphere Region

This document represents an evaluation of climate change vulnerability for sanderling in the Golden Gate Biosphere (GGB) region of California. The following information is based on stakeholder input provided during and following a winter 2022 vulnerability workshop as well as sources from the scientific literature.

Species Description

Sanderlings (*Calidris alba*) are small sandpipers associated with sandy beaches, which they utilize as migratory and non-breeding habitat across the globe (Macwhirter et al. 2020). They are highly recognizable by their foraging behavior, which involves chasing receding waves and probing the sand in search of small crustaceans and bivalves and then running back ahead of incoming waves (Macwhirter et al. 2020). While sanderlings primarily winter along coastal beaches, they can also be found on tidal mudflats, estuaries, and rocky intertidal areas (Kjelmyr et al. 1991; Macwhirter et al. 2020). Breeding occurs only on tundra in the high Arctic, where the greatest sanderling concentrations occur at high latitudes in Canada, Greenland, and Siberia (Macwhirter et al. 2020). They nest on the ground in shallow scrapes lined with leaves, alone or in loose colonies (Macwhirter et al. 2020). Nests typically contain 4 eggs, and both sexes participate in incubation, brooding, and attending precocial young until they reach fledging age (Macwhirter et al. 2020). As long-distance migrants, they travel several thousand miles annually and rely on a few key staging areas during migration (Myers et al. 1990; National Audubon Society 2023).

In California, sanderlings occur as spring and fall migrants as well as wintering birds (Kjelmyr et al. 1991). They are mostly absent from mid- to late-May through July, though occasional stragglers remain all summer. They are one of the most common overwintering shorebird in the Golden Gate Biosphere (GGB) region (Nielsen et al. 2013; NPS 2019) where mole crabs (*Emerita* spp.) are a favorite prey item (Vuln. Assessment Worksheets, pers. comm., 2022). They are especially common on the larger sandy beaches such as Limantour Beach, Drake's Beach and the Great Beach in the Point Reyes National Seashore and other pocket beaches north of Tomales Bay (Shuford et al. 1989; Vuln. Assessment Worksheets, pers. comm., 2022). They are also found in the sandier areas of coastal estuaries, including at Bolinas Lagoon, Limantour Estuary, Tomales Bay, and Bodega Bay (Kjelmyr et al. 1991; Page et al. 1999; Vuln. Assessment Worksheets, pers. comm., 2022). Sanderling populations that overwinter within the GGB region migrate north along the Pacific Flyway (Kjelmyr et al. 1991) and breed in the Canadian Arctic (Vuln. Assessment Worksheets, pers. comm., 2022).

Species Vulnerability → Moderate *(moderate confidence)*

Vulnerability is evaluated by considering the species' sensitivity and exposure to various climate and non-climate stressors as well as the species' adaptive capacity (i.e., ability to cope with these stressors), and is given a ranking of low, moderate, or high. The confidence ranking represents confidence in the accuracy of the ranking based on available scientific knowledge, and is similarly ranked on a scale from low to high.

Summary of species vulnerability

Sanderlings are highly likely to be impacted by climate stressors and disturbance regimes that reduce habitat availability and quality, including sea level rise, storm surge, and precipitation changes. Additionally, and perhaps most significantly, warmer temperatures are having major impacts on habitat suitability within their Arctic breeding range, and appear to be contributing to phenological mismatches between the timing of breeding and peak invertebrate prey availability. Key non-climate stressors for sanderlings include development, recreational use of beaches (especially vehicles and off-leash dogs), and oil spills, which are associated with habitat loss, disturbance and associated behavioral changes (i.e., reduced time spent foraging or roosting), and mortality. Other factors that have the potential to impact sanderlings include recovery of peregrine falcons, which prey on wintering birds, and non-native invasive species that may impact prey availability.

Although the global population trend is unknown, sanderlings have undergone significant population declines in California, likely as a result of factors such as habitat degradation and loss as well as increased disturbance from recreational use of beaches. However, the species is globally distributed and displays some flexibility in terms of wintering habitat use that may benefit them as climate changes increasingly impact habitat extent and suitability. Like other migratory shorebirds, they are dependent on habitat within multiple disparate locations (i.e., breeding areas, migratory stopover sites, wintering habitat), making them highly vulnerable to climate impacts and habitat loss in any of these locations. Management strategies that may support sanderling populations over the coming decades include beach and wetland restoration, though efforts may need to include increased focus on supporting landward transgression of these systems through managed retreat strategies. Stricter regulation of human beach use to reduce disturbances of foraging and roosting birds may also help sanderlings maximize their feeding opportunities and maintain good body condition prior to migration.

Sensitivity and Exposure → Moderate *(moderate confidence)*

***Sensitivity** is a measure of whether and how a species is likely to be affected by a given change in climate factors, climate-driven changes in disturbance regimes, and non-climate stressors. By contrast, **exposure** is a measure of how much change in these factors a species is likely to experience. Sensitivity and exposure are combined here into one score representing both components of vulnerability, with high scores corresponding to increased vulnerability and low scores suggesting a species is less vulnerable.*

Within California, sanderlings are classified as a species vulnerable to climate change (Gardali et al. 2012), largely due to habitat loss from sea level rise and warming temperatures in their Arctic breeding grounds (Galbraith et al. 2002; National Audubon Society 2023). One study modeling projected changes in climatically-suitable breeding habitat for Arctic migratory birds found that only 6–14% of the current breeding habitat extent for sanderlings was expected to remain suitable by 2070, depending on the emissions scenario used (Wauchope et al. 2017). Similarly, the National Audubon Society predicts losses of up to 80% of current sanderling breeding habitat in North America under global temperature increases of 2.0°C, and 97% if global temperatures increase by 3.0°C (National Audubon Society 2023). Because these birds are already breeding at very high latitudes, northward shifts in suitable conditions due to warming may result in these areas being pushed off the map (Meltofte et al. 2007; Wauchope et al. 2017). Warmer temperatures are likely to have less impact on the extent of wintering habitat. In fact, climatically suitable winter habitat is projected to increase by 57% under global temperature increases of 2.0°C (118% under increases of 3.0°C), with losses of only 8–9% of the current climatically suitable areas (National Audubon Society 2023). However, these projections do not take into account loss of beach habitat from sea level rise, which in the GGB region are expected to be significant. For example, at Point Reyes National Seashore, sandy beach habitat is expected to diminish by 32% at 2 meters (6.6 feet) of sea level rise (Neuman et al. 2021).

Sensitivity and future exposure to climate factors → High *(moderate confidence)*

- **Sea level rise** is a significant threat to sanderling and other shorebird populations within the GGB region and worldwide (Galbraith et al. 2002; National Audubon Society 2023). Because sanderlings rely exclusively on intertidal habitats for migration and overwintering (Macwhirter et al. 2020), sea level rise that results in the loss of sandy beaches and tidal mudflats would reduce or eliminate critical habitat (Galbraith et al. 2002). This is particularly concerning where adjacent infrastructure (e.g., seawalls, roads, buildings) limits inland shoreline migration (Dugan et al. 2008; Heady et al. 2018) that would otherwise have the potential to maintain intertidal zones that provide suitable foraging habitat.
- **Changes in precipitation patterns** within the GGB region may influence wintering sanderling populations, as multiple studies have shown correlations between reduced sanderling abundance and higher winter precipitation amounts (Stenzel & Page 2018; Warnock et al. 2021). In the Colorado River Delta, sanderling abundance also decreased significantly during a drought period (Hinojosa-Huerta et al. 2013).
- **Warmer air temperatures** are having disproportionate impacts on Arctic regions (Serreze & Barry 2011) where sanderlings migrate annually to breed and raise their young (Macwhirter et al. 2020). The Arctic is warming at rates twice that of the global average (Winton 2006; Serreze & Barry 2011), which is thought to be largely responsible for the expansion of shrubby vegetation into tundra ecosystems (Myers-Smith et al. 2011, 2015) that reduces habitat suitability for tundra-breeding birds (Boelman et al. 2015) such as sanderlings. Increasing

temperatures are also contributing to mismatches between the timing of breeding and peak food availability (Renner & Zohner 2018; Saalfeld et al. 2019), with the hatching date of sanderlings in northeastern Greenland showing little change even as peak arthropod abundance advanced by 1.3 days per year over the course of 17 years (Reneerkens et al. 2016). Increasing temperatures may also be driving range shifts of predatory bird species (Martínez-Ruiz et al. 2023) that could decrease survival rates of sanderlings on breeding and wintering grounds.

Sensitivity and future exposure to climate-driven changes in disturbances → Moderate *(low confidence)*

- **Increased storm surge** may negatively affect overwintering habitat by accelerating beach erosion and inundation, particularly in conjunction with rising sea levels (Feagin et al. 2005; Alpert 2016). While narrowing of the beach may be temporary, large storms can result in extreme coastal erosion that may have more lasting impacts on the ability of sanderlings to feed and roost on those beaches (Vuln. Assessment Worksheets, pers. comm., 2022). Winter storms are also known to disrupt invertebrate prey populations, contributing to lower prey capture rates and reduced weight in mid-winter birds (Maron & Myers 1985).
- **Climate-driven increases in disease outbreaks** may impact sanderlings, which, like other shorebirds are known to be susceptible to avian influenza A (H5N1; e.g., Hall et al. 2011). Avian influenza is widespread among wild birds, and ongoing spread is thought to be driven by the intercontinental movement of long-distance bird migration (Morin et al. 2018). Currently, a significant outbreak is occurring within North America, where a new strain was introduced in 2021 (Bevins et al. 2022). Within California, sanderling mortality as a result of avian flu has been documented in 2023 within three counties (Santa Cruz, San Francisco, and Sonoma; APHIS 2023), and anecdotal reports also suggest an infected bird was present at Limantour Beach in Marin County (Vuln. Assessment Worksheets, pers. comm., 2022). Climate changes such as warmer water temperatures and reduced salinity in coastal wetlands influenced by the influx of fresh water from heavy rainfall may allow the virus to persist within the environment for longer periods of time, potentially increasing disease prevalence (Morin et al. 2018). Indirectly, climate change may also influence patterns of disease transmission as changes occur in shorebird population dynamics, distribution, and migration (Gilbert et al. 2008; Morin et al. 2018). Finally, climate change may drive changes in pathogen survival and distribution, potentially allowing the introduction of novel diseases (Van Hemert et al. 2014).

Dependency on habitat and/or other species → High *(high confidence)*

Sanderlings that overwinter in the GGB region are dependent on sandy beaches and tidal mudflats as overwintering habitat, as well as migratory stopover sites within the Pacific Flyway and breeding habitat in the Canadian Arctic (Macwhirter et al. 2020). This increases their vulnerability to climate

changes, disturbances, and anthropogenic stressors that affect habitat quality and availability in any of these environments (Galbraith et al. 2002; Stralberg et al. 2010; Small-Lorenz et al. 2013). The coastal ecosystems they depend on for wintering and migratory habitat are highly vulnerable to sea level rise (Galbraith et al. 2002) and these areas also tend to experience high development pressure that reduces or eliminates suitable habitat for foraging and roosting by shorebirds (Stralberg et al. 2010), a phenomenon known as coastal squeeze (Schlacher et al. 2007). Additionally, sanderlings rely on relatively few key staging areas for migration (National Audubon Society 2023), putting them at particularly high risk if these areas were lost to development or climate-driven changes (Small-Lorenz et al. 2013; Vuln. Assessment Worksheets, pers. comm., 2022). Prey declines or other impacts that affect the ability to obtain sufficient food at migratory stopovers is also known to contribute to low survival rates after departure and is believed to have played a role in rapid declines in shorebird populations utilizing tidal flats at the Yellow Sea as staging areas (Studds et al. 2017), highlighting the importance of protecting these sites.

Wintering sanderlings forage on a variety of small crustaceans and bivalves, including sand crabs, isopods (*Excirolana* spp.), amphipods, insects, marine worms, and small mollusks (Maron & Myers 1985; Estelle 1991). Their use of multiple foraging areas (e.g., beaches, mudflats, tidal wetlands) likely reduces their vulnerability to climate-driven declines in a single prey type. However, a study in Bodega Bay documented significant weight declines in wintering sanderlings, which was correlated with lower prey availability over the course of the season (Maron & Myers 1985). This suggests there may be relatively little wiggle room for wintering birds in the region that face additional prey declines, including those that may be driven by ocean acidification associated with climate change (Kurihara 2008; Feely et al. 2016).

Sensitivity and current exposure to non-climate stressors → Moderate *(moderate confidence)*

Non-climate stressors can exacerbate ecosystem sensitivity to changes in climate factors and disturbance regimes, and/or can be exacerbated by these changes.

- **Residential/commercial development** that reduces beaches, tidal mudflats, and estuaries negatively impacts the extent of overwintering habitat and migratory stopover sites for sanderlings (Macwhirter et al. 2020). Development is also associated with roads and impervious surfaces that affect the hydrological function of estuaries and tidal wetlands, negatively impacting habitat quality (Duffy et al. 2016).
- **Recreational use of beaches**, in particular the presence of vehicles and off-leash dogs, has been shown to disrupt foraging and roosting behavior in sanderlings (Burger & Gochfeld 1991; Colwell & Sundeen 2000; Thomas et al. 2003; Borgmann 2010; Murchison et al. 2016; Macwhirter et al. 2020) and in some instances can displace birds from preferred feeding locations (Tarr et al. 2010). These disturbances increase stress and can be energetically expensive for shorebirds as they spend less time feeding and must burn energy avoiding approaching humans, dogs, and vehicles, which prevents them from building the fat reserves

necessary to survive migration (Thomas et al. 2003; Tarr et al. 2010; Murchison et al. 2016). Within the GGB region and elsewhere in the species' winter range, recreational use is particularly common on the wide, flat, sandy beaches preferred by sanderlings, increasing the likelihood of exposure to these disturbances (Vuln. Assessment Worksheets, pers. comm., 2022).

- **Oil spills** that affect shorelines and intertidal habitats within the GGB region have the potential to cause significant mortality and temporary loss of wintering habitat for shorebirds (Vuln. Assessment Worksheets, pers. comm., 2022), and sanderlings are more likely to be oiled than many other bird species due to their propensity to forage and roost along open sandy beaches (Burger 1997; Henkel et al. 2014). Following the November 2007 Cosco Busan Spill in the San Francisco Bay, shorebird surveys found that 76% of sanderlings in the area had visible oil on them, compared to just 17% of those on Marin County beaches (Warnock 2007). For migratory birds, frequent interruptions by cleanup personnel and vehicles on oiled beaches as well as increased time spent preening oiled feathers also reduce time spent foraging, with potential impacts to post-departure body condition and survival (Burger 1997; Henkel et al. 2014).
- The **recovery of peregrine falcons** (*Falco peregrinus anatum*) that prey upon wintering shorebirds may be a factor in sanderling declines, although the extent of this threat is not well-understood (Vuln. Assessment Worksheets, pers. comm., 2022). Studies of sanderlings in Australia found that the presence of peregrine falcons appeared to be associated with reduced body mass and changes in the pattern and speed of migration (Ydenberg et al. 2004; Hope et al. 2011). This suggests that increases in peregrine populations over the past several decades could impact the behavior and local population dynamics of sanderling populations in the GGB region (NPS 2019).
- **Non-native invasive species** such as the European green crab (*Carcinus maenas*) have been shown to reduce prey availability for wintering dunlin (*Calidris alpina*) in the Bay area, suggesting the potential for similar impacts on sanderlings (Estelle & Grosholz 2012). However, a literature survey found that the direct and indirect impacts of non-native invertebrates on shorebirds were overall variable depending on the species (Estelle & Grosholz 2012).

Adaptive Capacity → Moderate *(moderate confidence)*

Adaptive capacity *is the ability of a species to respond to or cope with climate change impacts with minimal disruption. High adaptive capacity corresponds to lower overall climate change vulnerability, while low adaptive*

capacity means that the species will be less likely to cope with the adverse effects of climate change, thus increasing the vulnerability of the species.

Species extent, status, connectivity, and dispersal ability → High (high confidence)

Sanderlings are a globally-distributed species, and wintering populations are widespread along the coasts of North and South America (Macwhirter et al. 2020), including on sandy beaches and tidal mudflats within the GGB region (NPS 2019). The broad distribution of this species suggests the potential for populations to utilize new wintering areas if local habitats are lost to sea level rise, development, or other stressors (Vuln. Assessment Worksheets, pers. comm., 2022). Although the species is ranked as Least Concern on the International Union for Conservation of Nature (IUCN) Red List (BirdLife International 2016), many regional populations are already declining (NABCI 2014; Macwhirter et al. 2020; Meehan et al. 2022) with some surveys finding declines of up to 80% since the 1970s (National Audubon Society 2023). In California, Christmas Bird Count surveys documented statewide declines of 3.7% per year from 1959–1988 and 0.56% per year from 1970–2021 (Macwhirter et al. 2020; Meehan et al. 2022). Within the GGB region, most surveys have found declines as well, although trends vary by beach and year (Stenzel & Page 2018; NPS 2019; Warnock et al. 2021). Within the Golden Gate National Recreation Area, sanderlings declined at 12 out of 14 beaches between 1994 and 2013, with an average decrease of 6% per year (NPS 2019). At Tomales Bay in Marin County, the abundance of wintering sanderlings declined by 44.2% between 1989 and 2019 (Warnock et al. 2021). However, at nearby Bolinas Lagoon, surveys found no statistically significant decline since 1997 (Stenzel & Page 2018). Taken as a whole, these trends correspond to broader declines in migratory shorebirds observed across North America (NABCI 2014; Rosenberg et al. 2019; Meehan et al. 2022; Smith et al. 2023) and globally (Smith et al. 2020; Koleček et al. 2021), likely as a result of habitat degradation and increased disturbance from recreational use of beaches (Macwhirter et al. 2020). These declines are likely to accelerate with sea level rise, warming temperatures, and other climate changes that cause the loss and degradation of wintering and breeding habitats and migratory stopover sites (Galbraith et al. 2002; Small-Lorenz et al. 2013).

As long-distance migrants, sanderlings fly distances up to 6,000 miles (for individuals traveling from the High Arctic to wintering grounds in South America; Macwhirter et al. 2020). As a result, they are considered to have high dispersal ability and are much less impacted by barriers than less mobile species (Vuln. Assessment Worksheeets, pers. comm., 2022). On their wintering grounds, adult sanderlings show relatively high site fidelity. For instance, of 30 wintering adult sanderlings captured in Bodega Bay and transplanted 200 km away, 60% returned to the capture site with most of those returning within 20 days (Myers et al. 1988). However, they also are known to move around within the region (distances of up to a few hundred kilometers) in response to rapidly-changing local prey populations (Myers 1980).

Intraspecific/life history diversity → Moderate (moderate confidence)

Sanderlings utilize a variety of winter foraging habitats, including open sandy beaches, intertidal mud flats, and the edges of tidal marshes and estuaries (Macwhirter et al. 2020). This flexibility has the potential to benefit them where climate-driven changes degrade or eliminate some areas. They also eat a variety of marine and wetland invertebrates (Maron & Myers 1985; Estelle 1991), which similarly helps buffer them against drastic declines in certain prey types. Less is known about population dynamics and mating systems of this species on their Arctic breeding grounds (Macwhirter et al. 2020). Their breeding range is very limited, though they can nest in a variety of substrates on the Arctic tundra (Vuln. Assessment Worksheets, pers. comm., 2022).

Genetic diversity within this species is relatively unstudied but may be high given their wide latitudinal distribution and convergence at Arctic breeding grounds (Vuln. Assessment Worksheets, pers. comm., 2022). Given their clustered breeding distribution, they are expected to have relatively large effective breeding populations (Macwhirter et al. 2020). However, this clustered distribution could also be associated with reduced adaptive capacity if it is associated with physical changes or unbalanced climate-driven changes in tundra breeding habitat (K. Neuman, pers. comm., 2023). Based on morphology and plumage differences, there are two recognized subspecies: *C. a. alba* breeding in northeastern Greenland, Ellesmere Island, Svalbard, and central Siberia, and *C. a. rubidus*, breeding in northern Alaska and the central Canadian Arctic (Engelmoer & Roselaar 1998). Although a complete examination of the genetic population structure has not yet been done, a more recent study found weak genetic differentiation between Greenland- and Siberia-breeding populations utilizing the East Atlantic Flyway that extends from western Europe to South Africa (Conklin et al. 2016).

Resistance and recovery → Low (moderate confidence)

The high mobility of migratory birds such as sanderlings confers some resistance to changing conditions by allowing individuals to easily avoid disturbed areas or seek out higher-quality habitat (Dolman & Sutherland 1995). However, the energetic and physiological cost of migration is high and the dependence of migratory birds on habitat availability in disparate locations increases the risk that one or more sites will be affected by climate change, development, oil spills, or other stressors (Dolman & Sutherland 1995; Small-Lorenz et al. 2013; Koleček et al. 2021). For Arctic breeding birds, such as sanderlings, there is little possibility of resisting the impacts of rapid climate change in the Arctic tundra, which include habitat loss and phenological shifts in the timing of peak prey availability (Vuln. Assessment Worksheets, pers. comm., 2022). Resilience to changes in habitat extent and quality may be higher during the non-breeding season, as the species' winter range is extensive and beaches and wetlands that have room to shift inland with rising sea levels will continue to provide overwintering habitat (Vuln. Assessment Worksheets, pers. comm., 2022).

Population recovery following declines is largely dependent on a combination of reproductive rates and adult survival. In general, shorebirds – including sanderlings – have relatively low reproductive

rates (i.e., often no more than 4 eggs per breeding year; Evans & Pienkowski 1984; Myers et al. 1987), which slows recovery from population decreases (Vuln. Assessment Worksheets, pers. comm., 2022). However, annual survivorship is generally high (Evans & Pienkowski 1984; Myers et al. 1987) and this can promote population growth. Increased climate impacts and continued habitat degradation and loss are likely to make recovery from population declines increasingly challenging in the coming decades (NABCI 2010).

Management potential → Low (moderate confidence)

Migratory shorebirds are generally intriguing to the public, and most people are familiar with sanderlings feeding along the shoreline even when they cannot identify them by name (Vuln. Assessment Worksheets, pers. comm., 2022). However, most people don't recognize the plight of Arctic-breeding shorebirds, nor are they aware of the significant population declines occurring in sanderlings and other species. Groups such as the National Audubon Society, Point Blue Conservation Science, and the Western Hemisphere Shorebird Reserve Network are strong advocates for shorebirds, as are birders in general. Societal support for conservation of sand beaches and tidal wetlands that provide critical wintering and migratory habitat to sanderlings is also strong in the GGB region. Wetlands have significant regulatory protections, and beach and tidal marsh restoration in the region is valued and generally well-funded and supported by the public (Vuln. Assessment Worksheets, pers. comm., 2022). However, limiting recreational impacts on beaches can be challenging, and climate change may further increase conflicts with recreational beach users seeking respite from extreme heat on sandy beaches (Vuln. Assessment Reviewer, pers. comm., 2023). People want to be able to access beaches at will and there is often pushback against restrictions on vehicles or off-leash dogs, which can result in shorebirds being repeatedly disturbed or displaced to more marginal habitats (Vuln. Assessment Worksheets, pers. comm., 2022). To build support for beach restrictions that benefit sanderlings and other migratory shorebirds, conservation managers need to develop programs to increase understanding of the negative effects of human-caused disturbance among beach users (Vuln. Assessment Reviewer, pers. comm., 2023). More funding is needed for these efforts and those that promote increased climate literacy among beach users, and this need will become more critical as the current level of support becomes increasingly inadequate to prevent declines in the face of growing climate stressors (Vuln. Assessment Worksheets, pers. comm., 2022).

Rising sea levels are likely to cause extensive loss of coastal habitat availability in areas where beaches are unable to shift inland due to development or other barriers (Galbraith et al. 2002; Vitousek et al. 2017). Identification and restoration of beaches, dunes, and tidal wetlands that are projected to be resilient to sea level rise has the potential to alleviate some of the impacts of climate change by increasing habitat extent and quality for overwintering sanderlings (Vuln. Assessment Worksheets, pers. comm., 2022). In many areas, sanderlings will also benefit from an increased focus on managed retreat strategies (i.e., moving or abandoning infrastructure rather than continuing efforts to prevent inevitable erosion and inundation) to allow for landward transgression of dunes and coastal wetlands

that serve as critical shorebird habitat (Galbraith et al. 2002; Bragg et al. 2021). Management strategies should also include a continued focus on eliminating disturbances from vehicles and off-leash dogs around foraging birds, in particular at critical migration staging areas, to ensure that migrating and overwintering sanderlings are able to acquire enough energy to survive their annual journey to their Arctic breeding grounds (Thomas et al. 2003). Finally, for migratory birds, it is critical to consider habitat conservation across the full life cycle (Small-Lorenz et al. 2013). Because sanderlings concentrate at relatively few key staging areas (National Audubon Society 2023), it will be particularly important to protect these areas from development or other impacts that would reduce their availability or quality for migrating shorebirds (Iwamura et al. 2013). Despite their importance, efforts such as these can present additional challenges related to coordinating conservation across geopolitical boundaries (Small-Lorenz et al. 2013).

Recommended Citation

EcoAdapt. 2024. Sanderling (*Calidris alba*): Climate change vulnerability assessment summary for the Golden Gate Biosphere region. EcoAdapt, Bainbridge Island, WA.

Further information on the Golden Gate Biosphere Region Climate Adaptation Project is available on the project page (www.ecoadapt.org/goto/GGBRClimateProject).

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