Coastal Bluffs and Scrub

Northern California Climate Change Vulnerability Assessment Synthesis

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for coastal bluffs and scrub in northern California based on expert input and existing information. Specifically, the information presented below comprises vulnerability factors selected and scored by regional experts, relevant references from the scientific literature, and peer-review comments and revisions (see end of document for a glossary of terms and brief overview of study methods). The aim of this document is to expand understanding of habitat vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.*

Peer reviewers for this document included Adam Canter (Wiyot Natural Resources Department), Laurel Goldsmith (U.S. Fish and Wildlife Service), and Sara Hutto (Greater Farallones Association). Vulnerability scores were provided by Laurel Goldsmith.

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Habitat Description

In northern California, coastal bluffs and scrub occurs in a narrow, discontinuous band along the Pacific coast from the Oregon border south to Monterey County (Ford & Hayes 2007). The habitat group comprises coastal bluff and associated marine terrace communities, which can extend up to 45 km (20 mi) inland (de Becker 1988; Heady et al. 1988; Baxter & Parker 1999). Adjacent to the ocean or bays, nearly vertical unconsolidated bluffs support sparse plant communities dominated by herbaceous species and low shrubs that are adapted to an unstable substrate, salt-laden air, and salt-accumulating soils (Ford & Hayes 2007; Thorne et al. 2016). On the nearly-level marine terraces, coastal scrub vegetation tends to grow more densely, and plant communities consist of a low to moderately sized (<2 m [<6.6 ft]) shrub overstory and a distinct herbaceous understory (Ford & Hayes 2007). In Mendocino County, coastal bluff and scrub vegetation is generally dominated by coyote brush (*Baccharis pilularis*), a native evergreen shrub (Belsher 1999; CNPS 2019). In Humboldt and Del Norte Counties, coastal bluff and scrub vegetation typically includes a mix of coyote brush, salmonberry (*Rubus spectabilis*), and thimbleberry (*R. parviflorus*; Belsher 1999).[1]

In California, coastal scrub exhibits distinct northern (mesic) and southern (xeric) variations, with the former type found on marine terraces in the cool, moist climate of the northern California coast (Holland & Keil 1995; Ford & Hayes 2007; Thorne et al. 2016). In northern California, plant composition changes progressively from more evergreen species in the north to a greater proportion of drought-deciduous species in the south (Holland & Keil 1995; Ford & Hayes 2007). Plant communities also vary widely within the region depending on microclimate, soil, topography, disturbance history, and historical and contemporary land use (de Becker 1988; Baxter & Parker 1999; Ford & Hayes 2007; Cornwell et al. 2012). Northern coastal scrub vegetation often intergrades with coastal prairies, forming a mosaic across the marine terrace landscape interrupted by oak woodlands, conifer and hardwood forests, and fresh and saltwater marshes (Ford & Hayes 2007).

Coastal bluffs and scrub are important for northern California tribes and contain many cultural sites, burial areas, and shell mounds (HWR Engineering & Science 2010; Sloan & Hostler 2014; Chiniewicz 2015; Norgaard et al. 2016). Northern California tribes gather grasses, roots, hazelnuts, acorns, and berries from these habitats for food, fiber, medicines, and basketry materials (Anderson 2005; Sloan & Hostler 2014; Norgaard et al. 2016; Vuln. Assessment Workshop, pers. comm., 2017). Coastal bluff and scrub habitats, including rare areas dominated by California hazelnut (*Corylus cornuta californica*) and those that include salmonberry and thimbleberry, were managed by the Wiyot Tribe around Humboldt Bay through periodic burning to promote better berry crops and stimulate the growth of basketry sticks (Driver 1939). Coastal bluffs and scrub also serve as important access points for tribe members gathering resources from adjoining riverine and marine habitats (e.g., fish, mollusks, and seaweed; Norgaard 2014; Sloan & Hostler 2014; Norgaard et al. 2016; Vuln. Assessment Workshop, pers. comm., 2017).

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[1] Please note that the research base for coastal bluff/scrub vegetation in northern California is sparse compared to other areas of the state. Some of the research cited in this assessment originates from the central California coast, and, to a lesser extent, the southern California coast. Results of these studies should be interpreted and applied with caution until more is known about how the ecology of northern California coastal scrub vegetation functions in comparison to coastal scrub communities elsewhere in the state.

Executive Summary

The relative vulnerability of coastal bluffs and scrub in northern California was evaluated as moderate by regional experts due to moderate-high sensitivity to climate and non-climate stressors, moderate exposure to projected future climate changes, and low-moderate adaptive capacity.

Coastal Bluffs and Scrub	Rank	Confidence
Sensitivity	Moderate-High	Moderate
Future Exposure	Moderate	Low
Adaptive Capacity	Low-Moderate	Moderate
Vulnerability	**Moderate**	**Moderate**

Sensitivity & Exposure Summary	
	Climate and climate-driven factors: • Sea level rise, precipitation amount, climatic water deficit, soil moisture, drought, air temperature *Disturbance regimes*: • Storms, flooding, wind, wildfire *Non-climate stressors*: • Invasive species, roads/highways/trails, fire suppression, residential and commercial development, livestock grazing

Coastal bluffs and scrub are sensitive to factors that impact plant water availability, disturb succession regimes for key plant species, and increase bluff erosion. For instance, changes in precipitation are likely to alter species composition and distribution, with soil moisture corresponding closely to patterns of coastal scrub expansion (under wetter conditions) or contraction (under drier conditions). Coastal bluffs and scrub are also vulnerable to bluff erosion from storms, flooding, and sea level rise, which may eliminate habitat, hinder vegetation growth, and/or cause plant mortality. Wildfire can slow tree encroachment and increase vegetation productivity. Non-climate stressors such as invasive species can outcompete native vegetation, decrease plant productivity, and provide fewer resources for northern California tribes and wildlife. Roads and development have resulted in the loss and fragmentation of this habitat, and development pressure remains high in coastal areas. Additionally, while carefully managed grazing can help maintain habitat integrity and extent, overgrazing damages native plants and encourages the growth of invasive species. Finally, fire suppression has impacted habitat quantity and quality in the region, with the encroachment of conifers and hardwoods potentially resulting in the conversion of coastal scrub vegetation to woodlands.

Adaptive Capacity Summary	
	Factors that enhance adaptive capacity: + Rapid recolonization of highly disturbed coastal areas and adjacent grasslands + Rapid response to land use and management changes increases restoration potential + Diverse plant assemblages reflect a range of climate niches *Factors that undermine adaptive capacity*: – High habitat fragmentation due to heavy development pressure in coastal areas – Reduced plant species diversity in some areas due to loss of historical disturbance regimes – Lack of public support for prescribed burning due to perceived risk – Bluffs likely to retreat with rising sea levels, reducing habitat extent

Coastal bluff and scrub habitats are discontinuous in northern California, existing in a relatively narrow zone along the coast within preserves, ranchlands, and commercial/residential areas where development pressure is high. Some areas of mature, structurally diverse coastal bluff and scrub vegetation with a high proportion of native grass and forb species exists in the region, although many areas of low plant diversity are also present. Resistance to climate stressors is supported by plant species that respond rapidly to changes in climate conditions (e.g., soil moisture) and recurring disturbances (e.g., grazing, fire, bluff face erosion) and that are able to colonize new areas relatively quickly. As sea levels rise, these traits may allow reestablishment as landforms change and unconsolidated bluffs erode landward. However, habitat will likely be lost as bluffs retreat due to sea level rise and changes in storm frequency and severity. Public understanding of this habitat is limited, although it is highly valued by northern California tribes and is gaining research attention. The scientific literature suggests a number of strategies that may be key in preserving habitat extent and increasing habitat quality as the climate changes, including cultural/prescribed burning, sound livestock grazing methods, and managing coastal bluff retreat.

Sensitivity and Exposure

Coastal bluffs and scrub were evaluated by regional experts as having moderate-high overall sensitivity (moderate confidence in evaluation) and moderate overall future exposure (low confidence) to climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors.

Climate changes are projected to alter the extent of coastal bluffs and scrub, primarily due to precipitation and soil moisture changes, drought, sea level rise, and increasing frequency and severity of storms and flooding (Williams & Hobbs 1989; Ford & Hayes 2007; Collins & Sitar 2008; Cornwell et al. 2012; Pettit et al. 2014). Coastal bluffs and scrub also exhibit some sensitivity to warming air temperatures,

Potential Changes in Habitat Distribution by 2100
• 42–92% of the statewide current distribution of coastal bluff and dune vegetation is expected to experience an increase in climatic stress, while 0–41% will remain within climatically suitable areas • 2–20% of the projected climatically suitable area in 2100 may occur in newly suitable areas
Source(s): Thorne et al. 2016

however, the heterogeneous topography characteristic of these habitat areas is likely to provide microrefugia from temperature extremes for some plant species (Ackerly 2003; Wrubel & Parker 2018).

Habitat distribution modeling by Thorne et al. (2016, 2017) projects areas of future climatic exposure (i.e., areas likely to experience significant environmental stress and/or type conversion) and climatic suitability for coastal bluff and dune vegetation by the end of the century.[2] Between 42–92% of the currently mapped area of coastal bluff and dune vegetation statewide is projected to experience a significant increase in environmental stress and/or to become climatically unsuitable by 2100. Habitat exposure is likely to be greatest under a high-emissions scenario with warmer/wetter conditions, particularly in western Humboldt and Del Norte Counties. Comparatively, between 0–41% of the currently mapped extent of coastal scrub vegetation will remain in climatically suitable areas. Finally, by the end of the century, 2–20% of the projected climatically suitable area for this vegetation group may occur in newly suitable areas. The largest expansions are projected to occur in northwestern California under the hottest/driest scenarios (Thorne et al. 2016, 2017).

Sensitivity and future exposure to climate and climate-driven factors

Regional experts evaluated coastal bluffs and scrub as having moderate-high sensitivity to climate and climate-driven factors (moderate confidence in evaluation), with an overall moderate-high future exposure to these factors within the study region (moderate confidence). Key climatic factors that affect coastal bluffs and scrub include sea level rise, precipitation amount, climatic water deficit, soil moisture, drought, and air temperature.[3]

<u>Sea level rise</u>

Sea level rise is likely to exacerbate erosion in coastal bluffs and scrub over the coming century as higher wave events weaken and erode exposed bluffs (Collins & Sitar 2008; Pettit et al. 2014). Projections of sea level rise and associated erosion based on historic sea level rise rates suggest that coastal bluffs along the U.S. West Coast may retreat 10–30 m (32.8–98.4 ft) by 2100 (Griggs & Patsch 2004; National Research Council 2012). However, continued acceleration in the rate of sea level rise could result in even higher rates of coastal bluff retreat (National Research Council 2012). Sea level rise impacts are likely to be greatest in the Humboldt Bay area where relative sea level is rising at a greater rate than the global average due to land subsidence associated with shifting tectonic plates (National Research Council 2012; Chiniewicz 2015; NHE 2015; Patton et al. 2017; Laird 2018). By contrast, land uplift in the broader region

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[2] Projections in this study are based on two different future climate models, MIROC ESM (warmer and drier) and CNRM CM5 (warmer and wetter), and two future greenhouse gas emissions scenarios, RCP 8.5 (business as usual emissions) and RCP 4.5 (Paris Accord target emissions). These scenarios encompass minimum temperature increases of 1.9–4.5°C (3.42-8.1°F) and a -24.8 to +22.9% change in precipitation by 2100 relative to 1980–2010 (Thorne et al. 2016, 2017).

[3] Climate and climate-driven factors presented are those ranked as having a moderate or higher impact on this habitat type; additional climate and climate-driven factors that may influence the habitat to a lesser degree include precipitation timing.

north of Cape Mendocino is likely to reduce the relative rate of sea level rise (National Research Council 2012; NHE 2015; Patton et al. 2017).

The retreat of coastal bluffs and loss of marine terrace vegetation is most likely in areas that lack wave-deposited sediment to restore protective beaches or where beaches are absent (Griggs & Patsch 2004; Pettit et al. 2014). Protective beaches fronting bluffs may widen or contract in size based on site-specific characteristics that affect sediment deposition and erosion (Hesp 2002; Rader et al. 2018). However, rapid sea level rise, in association with increases in storm frequency and/or intensity, is likely to inundate low-lying terraces (Russell & Griggs 2012) and increase erosion in areas of exposed bluffs (Yoshiyama & Moyle 2010).

Tribal cultural sites in coastal bluff and scrub are also vulnerable to damage and erosion from sea level rise (Chiniewicz 2015; Laird 2018). In Tolowa Dunes State Park, located in extreme northwestern California, bluff and dune erosion due to sea level rise has already begun to expose tribal cultural sites and archeological resources to damage, and this pattern is likely to continue (Chiniewicz 2015). Around Humboldt Bay, four of the 52 Wiyot cultural sites that are vulnerable to sea level rise are also threatened by bluff erosion and retreat (Laird 2018). These sites hold immense importance to the Wiyot Tribe as ceremonial and gathering areas and are part of the larger Wiyot cultural landscape (Vuln. Assessment Reviewer, pers. comm., 2018). One hundred percent of respondents in a recent survey given at the Wiyot Table Bluff Reservation believe that sea level rise and climate change are threats that the Wiyot Tribe should address through adaptation and mitigation planning and action (Vuln. Assessment Reviewer, pers. comm., 2018; WNRD 2018).

Regional Sea Level Rise Trends[4]	
Historical & current trends: • At the Crescent City station, sea levels decreased by an average of 0.08 cm (0.03 in) per year from 1933–2018 (equivalent to a decrease of 0.08 m [0.26 ft] in 100 years; NOAA/National Ocean Service 2019) • At the Humboldt Bay (North Spit) station, sea levels increased by an average of 0.49 cm (0.19 in) per year from 1977–2018 (equivalent to an increase of 0.49 m [1.6 ft] in 100 years; NOAA/National Ocean Service 2019)	*Projected future trends:* • Sea level rise trends by 2100 (compared to 2000), based on likelihood of occurrence (range includes projections linked to low-, moderate-, and high-emissions scenarios; Kopp et al. 2014; Griggs et al. 2017; Sweet et al. 2017; Anderson 2018): ○ For the Crescent City station, likely (66% probability) range of 0.03–0.65 m (0.1–2.1 ft), 0.5% probability will meet or exceed 1.55 m (5.1 ft); extreme scenario

[4] Trends in climate factors and natural disturbance regimes presented in this and subsequent summary tables are not habitat-specific; rather, they represent broad trends and future projections for the study region. The precipitation, temperature, climatic water deficit, and snowpack projections for this project are derived from the Basin Characterization Model, which uses modified Jepson ecoregions (Flint et al. 2013; Flint & Flint 2014). Projections for all other factors are based on a review of relevant studies in the scientific literature. For this project, exposure was evaluated by calculating the magnitude and direction of projected change within the modified Jepson ecoregions that include habitat distribution within the study geography.

Regional Sea Level Rise Trends[4]	
• At the Arena Cove station, sea levels increased by an average of 0.08 cm (0.03 in) per year from 1978–2018 (equivalent to a change of 0.08 m [0.27 ft] in 100 years; NOAA/National Ocean Service 2019)	(representing ice sheet collapse) of 2.79 m (9.1 ft) ○ For the Humboldt Bay (North Spit) station, likely (66% probability) range of 0.62–1.24 m (2.0–4.1 ft), 0.5% probability will meet or exceed 2.15 m (7.0 ft); extreme scenario (representing ice sheet collapse) of 3.37 m (11.0 ft) ○ For the Arena Cove station, likely (66% probability) range of 0.21–0.94 m (0.7–3.1 ft), 0.5% probability will meet or exceed 2.04 m (6.7 ft); extreme scenario (representing ice sheet collapse) of 3.02 m (9.9 ft)

Summary of Potential Impacts on Habitat *(see text for citations)*
• Accelerated bluff erosion, particularly in conjunction with storm-related waves • Increased inundation of low-lying terraces • Damage or loss of tribal cultural areas and artifacts

Precipitation amount, climatic water deficit, and soil moisture

In the maritime climate of northern coastal California, up to 90% of precipitation falls between October and April and high humidity is maintained during the rest of the year, with May through September characterized by fog and clouds (Wiedemann 1984; HWR Engineering & Science 2010; Alpert 2016). Changes in precipitation and soil moisture may alter habitat extent, plant recruitment success, and species composition in coastal bluffs and scrub (Ford & Hayes 2007; Cornwell et al. 2012). In general, drier conditions increase the risk of coastal bluff/scrub conversion to grass-dominated communities (Ford & Hayes 2007; Cornwell et al. 2012), while wetter conditions may allow coastal scrub to expand into adjacent habitats, particularly coastal prairies (Williams & Hobbs 1989; Ford & Hayes 2007). However, greater moisture stress associated with increases in climatic water deficit (CWD) are likely to inhibit plant growth even in areas where precipitation may increase due to enhanced evaporative demand as air temperatures rise (Thorne et al. 2015; Micheli et al. 2018).[5] The response of this habitat type to changes in water availability is likely to be influenced by the heterogeneous topography and diversity of plant types (Ford & Hayes 2007; Cornwell et al. 2012).

Low levels of precipitation early in the growing season (i.e., late winter/early spring) can negatively affect the growth and recruitment of coyote brush, particularly on drier sites (Williams & Hobbs 1989; Steinberg 2002; CNPS 2019). Coyote brush often occurs with annual

[5] CWD provides a "plant-relevant" metric to account for the interaction between water (precipitation) and energy (temperature) (Stephenson 1998). CWD, calculated as potential evapotranspiration (PET) minus actual evapotranspiration (AET), measures the degree to which the impact of local atmospheric conditions (particularly air temperature and relative humidity) on plants and soil exceeds available moisture (Stephenson 1998).

grasses, which have high transpiration rates early in the spring that reduce growing season soil moisture for other species (Williams & Hobbs 1989; Steinberg 2002; CNPS 2019). Thus, coyote brush establishment and growth may be hindered if low levels of spring precipitation reduce soil moisture within the initial rooting depth of this species (da Silva & Bartolome 1984; Williams & Hobbs 1989; Ford & Hayes 2007) and/or if seedling roots do not reach deeper areas of soil moisture before annual grasses begin their rapid spring growth (Davis & Mooney 1985; Williams & Hobbs 1989; Eliason & Allen 1997). In addition, coyote brush develops a long taproot after the initial spring growth period that helps the plant endure late-summer drought by utilizing moisture deep within the soil (da Silva & Bartolome 1984; Williams & Hobbs 1989; Ford & Hayes 2007). However, the taproot must grow rapidly enough to reach adequate soil moisture before the onset of the summer drought period (da Silva & Bartolome 1984; Williams & Hobbs 1989; Ford & Hayes 2007). Consequently, precipitation is a key limiting factor for successful coyote brush recruitment and growth throughout the growing season (da Silva & Bartolome 1984; Williams & Hobbs 1989; Ford & Hayes 2007).

Although coyote brush is sensitive to reduced precipitation at the beginning of the growing season, this species is adapted to low levels of soil moisture during the dry summer months, primarily through the use of fog water harvested by neighboring grass species, which wets shallow soil layers in the vicinity of coyote brush seedlings (Kidder 2015). However, if both rain and fog water inputs are limited later in the growing season, very low soil moisture can lead to severe soil cracking that can kill coyote brush (McBride & Heady 1968). In coastal scrub dominated by the coastal bramble alliance (i.e., salmonberry, thimbleberry, California blackberry [*Rubus ursinus*]), drier conditions could favor conversion to more xeric coyote brush dominance (Belsher 1999). Additionally, the presence of non-native species may further inhibit growth and increase competition for soil moisture among shallow-rooted native shrubs (D'Antonio & Mahall 1991). For instance, a study conducted in southern California suggests that the non-native, mat-forming iceplant (*Carprobotus edulis*) can displace the roots of native shrub species downward, thereby capturing soil moisture that would otherwise have been available to the native shrubs (D'Antonio & Mahall 1991).

Coastal shrub species are likely to benefit if precipitation and soil moisture increase (Williams & Hobbs 1989; Ford & Hayes 2007). For instance, increased rainfall in spring can result in the expansion of coyote brush into grasslands (da Silva & Bartolome 1984; Williams & Hobbs 1989; Steinberg 2002; Cornwell et al. 2012; Smither-Kopperl 2016). Once established after a wet year, coyote brush roots are able to utilize deeper soil water, increasing survival rates through the next dry season (Williams et al. 1987). Hence, a brief period of heavy rainfall early in the growing season can trigger the transition from grassland to coyote brush scrub (Williams et al. 1987). In addition, an increase in early season precipitation in the absence of disturbance can lead to the encroachment of hardwoods such as California bay (*Umbellularia californica*) into shrublands (McBride 1974; Steinberg 2002). As shrubs and trees grow, coastal scrub habitat becomes more structurally diverse (Hobbs & Mooney 1987; Williams & Hobbs 1989; Rowntree 1994; Steinberg 2002), providing cover for small mammals that reduce the herbaceous understory (Westman 1981).

An increase in precipitation, particularly heavy rainfall, may reduce the areal extent of coastal bluffs and scrub by accelerating bluff weathering and erosion (Collins & Sitar 2008; Pettit et al. 2014). Uncompacted to moderately compacted bluffs are the most vulnerable to fracture and potential failure due to heavy precipitation events (Collins & Sitar 2008; Pettit et al. 2014).

Regional Precipitation, Soil Moisture, and Climatic Water Deficit (CWD) Trends	
Historical & current trends: • 7.2 cm (2.8 in) increase in mean annual precipitation and 0.4 cm (0.2 in) increase in average annual CWD between 1900 and 2009 for the Northwestern California ecoregion (Rapacciuolo et al. 2014) • No trends available for soil moisture	*Projected future trends:* • 20% decrease to 27% increase in mean annual precipitation and 9–29% increase in average annual CWD by 2100 (compared to 1951–1980) for the North Coast ecoregion (Flint et al. 2013; Flint & Flint 2014)[6] • Seasonal changes are projected to be more significant as the wet season becomes wetter and shorter (i.e., later onset of fall rains and earlier onset of summer drought) and the dry season becomes drier and longer (Pierce et al. 2018; Swain et al. 2018) • Overall, interannual variability is expected to increase (Pierce et al. 2018; Swain et al. 2018) • Increased CWD and decreased top-level soil moisture is likely even if precipitation increases due to temperature-related changes in evaporative demand (Thorne et al. 2015; Micheli et al. 2018; Pierce et al. 2018)
Summary of Potential Impacts on Habitat *(see text for citations)*	
• Decreased plant productivity due to increased growing season moisture stress • With increased moisture stress, plant community transition to more xeric species • Increased shrub competition with invasive grasses for early season soil moisture, particularly if spring precipitation declines • Possible expansion of coastal scrub vegetation into adjacent habitats (i.e., coastal prairies and dune systems) during wet years • Possible tree encroachment and/or type conversion of coastal shrublands to woodlands if increased precipitation in the absence of disturbance • Accelerated bluff erosion and potential habitat loss due to increased winter precipitation, particularly during heavy rains	

Drought

Periods of severe drought may reduce the extent (Cornwell et al. 2012), productivity (Mooney & Dunn 1970), richness, and total herbaceous cover of coastal bluff and scrub vegetation

[6] Projections for changes in seasonal precipitation can be found at in the full climate impacts table (https://bit.ly/2LHgZaG).

(Kimball et al. 2014; Copeland et al. 2016). Recruitment in shrubs that reproduce by seed is reduced during periods of drought, especially where seed density of exotic annual grasses is high (da Silva & Bartolome 1984; Corbin et al. 2005). However, plant species that reproduce primarily by seed may also recover more rapidly from severe drought compared to those that resprout from roots (Ackerly et al. 2015). Prolonged droughts may also allow species more typical of southern coastal scrub communities to expand their range northward (Cornwell et al. 2012; Vuln. Assessment Reviewer, pers. comm., 2018).

Regional Drought Trends	
Historical & current trends: • Drought years have occurred twice as often over the last two decades compared to the previous century (Diffenbaugh et al. 2015) • 2012–2014 drought set records for lowest precipitation, highest temperatures, and most extreme drought indicators on record (Griffin & Anchukaitis 2014; Diffenbaugh et al. 2015)	*Projected future trends:* • Drought years are twice as likely to occur over the next several decades due to increased co-occurrence of dry years with very warm years (Cook et al. 2015) • 80% chance of multi-decadal drought by 2100 under a high-emissions scenario (Cook et al. 2015) • Severe droughts that now occur once every 20 years will occur once every 10 years by 2100 and once-in-a-century drought will occur once every 20 years (Pierce et al. 2018)
Summary of Potential Impacts on Habitat *(see text for citations)*	
• Reduced plant productivity • Reduced herbaceous cover and species richness • During drought, reduced recruitment of shrubs that reproduce by seed • After drought, more rapid growth of species that reproduce by seed rather than by resprouting • Increased abundance of drought-tolerant native and invasive species more typical of southern coastal scrub communities	

<u>Air temperature</u>

Warmer air temperatures are likely to increase moisture stress in coastal bluff and scrub habitats due to increased evaporative demand, contributing to drier conditions that may hinder growth (Ackerly et al. 2015; Thorne et al. 2015; Micheli et al. 2018). However, proximity to the ocean may buffer warming trends to some degree, leading to less exposure to climate extremes than for inland areas (Ford & Hayes 2007; Ackerly et al. 2015). Coastal vegetation also have traits that lessen impacts from higher air temperatures, including smaller or more highly dissected leaves that are tolerant of higher temperatures and shorter maximum heights (Cornwell et al. 2012). Warmer winter temperatures may allow coyote brush to expand into areas currently dominated by coastal prairie grasses (Cornwell et al. 2012), particularly when combined with greater late spring rainfall (Williams et al. 1987; Williams & Hobbs 1989).

Coastal bluff and scrub vegetation provides important resources for pollinators due to its abundant pollen and nectar production (Smither-Kopperl 2016). However, increasing air temperatures may cause a mismatch in the timing of plant flowering and insect migrations or life cycles, which can result in reduced seed set and decreased recruitment for insect-pollinated plant species (Memmott et al. 2007). In response to a warming climate, butterfly emergence and migratory arrival has already exhibited mismatches with the first flowering of herbs, which may indicate increasing asynchrony in insect–host plant interactions (Parmesan 2007).

Regional Air Temperature Trends	

Historical & current trends:
• 0.2°C (0.04°F) increase in the average annual temperature between 1900 and 2009 for the Northwestern California ecoregion (Rapacciuolo et al. 2014)
  ○ No seasonal temperature trends available
	Projected future trends:
	• 2.2–5.2°C (4.0–9.4°F) increase in the average annual temperature by 2100 (compared to 1951–1980) for the North Coast ecoregion (Flint et al. 2013; Flint & Flint 2014)
	  ○ 1.9–4.5°C (3.4–8.1°F) increase in average winter minimum temperatures
	  ○ 2.3–6.1°C (4.1–11.0°F) increase in average summer maximum temperatures

Summary of Potential Impacts on Habitat *(see text for citations)*	
• Reduced plant growth due to warmer temperatures in combination with drier conditions • Possible expansion of coyote brush into coastal prairie, particularly if spring precipitation increases • Increased asynchrony in insect–host plant interactions	

Sensitivity and future exposure to changes in natural disturbance regimes

Regional experts evaluated coastal of coastal bluffs and scrub as having high sensitivity to changes in natural disturbance regimes (high confidence in evaluation), with an overall low-moderate future exposure to these stressors within the study region (low confidence). Key natural disturbance regimes that affect coastal of coastal bluffs and scrub include storms, flooding, wind, and wildfire.

<u>Storms, flooding, and wind</u>

More frequent and/or more intense storms with large waves and high winds are likely to increase flooding and bluff erosion, with possible failure where erosion at the base undercuts the bluff (Griggs & Patsch 2004; Collins & Sitar 2008; Hanak & Moreno 2012; Russell & Griggs 2012; Pettit et al. 2014). Wind velocity affects local wave height and impacts on coastal of coastal bluffs and scrub (Wingfield & Storlazzi 2007; Largier et al. 2010). The most significant cliff erosion events occur when major storms coincide with high tides, which is particularly common during El Niño years when storm events are larger (Collins & Sitar 2008; Pettit et al. 2014). Sea level rise contributes further to wave height, exacerbating the impacts of storm surge and bluff erosion that reduce habitat extent (Griggs & Patsch 2004; Hanak & Moreno 2012; Russell & Griggs 2012). Flooding along marine terraces can increase bluff erosion and ground saturation that further destabilizes coastal bluffs and scrub (Largier et al. 2010).

Plants that grow on bluff faces, such as the prostrate form of coyote brush, are well-adapted to heavy onshore winds (Steinberg 2002). However, given their location at the ocean edge, bluff-face plant communities are vulnerable to changes in the frequency and intensity of storms that increase storm surge, wind, and salt spray (Kumler 1963; Wiedemann 1984). Although coastal shrubs and herbaceous plants are typically more tolerant of salt spray at moderate intensities compared to those growing inland (Oosting 1945; Kumler 1963; Wiedemann 1984), plants on bluffs and low-elevation marine terraces may be killed or have their tops pruned by salt spray during storm events (Kumler 1963; Wiedemann 1984). Seedlings and new vegetative growth are particularly vulnerable (Oosting 1945; Kumler 1963; Wiedemann 1984), and salt spray is likely one of the factors that prevents tree establishment in open coastal habitats (Wiedemann 1984; Griffiths & Orians 2003). Rain occurring during and after storm events can reduce the impact of salt spray by diluting it; without rain, the damage can be severe (Oosting 1945; Kumler 1963; Belsher 1999).

<table>
<tr><th colspan="2">Regional Storm, Flooding, & Wind Trends</th></tr>
<tr><td>Historical & current trends:
• Decline in the frequency of extreme two-day precipitation events between 1950 and 2009, with a slight decrease in the amount of precipitation received during extreme two-day events (Mass et al. 2010)
• Alongshore winds increased from 1940-1990 (Bakun 1990; Schwing & Mendelssohn 1997; Mendelssohn & Schwing 2002)
• No trends available for flooding or storm-related wind events</td><td>Projected future trends:
• Increase in storm intensity and duration, resulting in greater maximum precipitation rates and volume (Dettinger 2011; Shields & Kiehl 2016; Prein et al. 2017)
• Slight to moderate increase in storm frequency (up to 30% increase in atmospheric river days, or ~2.5 days per year; Dettinger 2011)
• Projected statewide increases in daily extreme precipitation values of 5–20% by 2100 (Pierce et al. 2018)
• More frequent/severe winter flooding due to an increase in extreme precipitation events (Dettinger 2011; AghaKouchak et al. 2018; Swain et al. 2018; Grantham et al. 2018)
• State-wide, 200-year floods are expected to increase in frequency by 300–400%, becoming 50-year floods (Swain et al. 2018)
• Alongshore winds increased from 1940-1990 (Bakun 1990; Schwing & Mendelssohn 1997; Mendelssohn & Schwing 2002)
• No projections available for storm-related wind events</td></tr>
<tr><th colspan="2">Summary of Potential Impacts on Habitat (see text for citations)</th></tr>
<tr><td colspan="2">• Increased bluff erosion, failure, and/or retreat due to storm surge, flooding, and wind
• Inhibited plant growth and possible mortality from salt spray and wave impacts</td></tr>
</table>

Wildfire

Wildfire occurs less frequently in coastal habitats compared to many other habitat types in California, likely due to cooler, moister conditions and relatively fewer lightning strikes in coastal areas (Cooper 1958; Green 1999; Stuart & Stephens 2006; Forrestel et al. 2011). Fog, in particular, may be an important factor limiting wildfire disturbance in coastal vegetation by decreasing summer drought stress and associated fuel moisture loss in some coastal shrub species (Emery et al. 2018). Large fires do occasionally occur in coastal areas, and they are typically associated with Pacific high pressure systems that produce warm, dry east winds (Schroeder et al. 1964; Stuart & Stephens 2006). Like other shrublands in California's Mediterranean-type climate, northern coastal scrub develops a high fire hazard over time due to dense accumulation of woody fuel and long periods of low precipitation (Ford & Hayes 2007).

Historically, wildfire was a significant driver of coastal bluff and scrub extent, species composition, and ecosystem functioning (Vuln. Assessment Workshop, pers. comm., 2017). Historically, coastal scrub vegetation likely burned at 20– to 30-year intervals (Greenlee 1983), primarily through tribal burning practices (Lewis 1973). Historical records and more recent observations of coastal grasslands suggest that coyote brush scrub was less extensive during the period of cultural burning than it is today (McBride & Heady 1968). Recurrent fire likely maintained adjacent grasslands by limiting shrub encroachment, and also limited tree encroachment in coastal scrub stands (Ford & Hayes 2007). Wildfire can benefit this habitat type by increasing plant species richness (Ford & Hayes 2007; Vuln. Assessment Workshop, pers. comm., 2017).[7]

Regional Wildfire Trends	

Historical & current trends:
• Changes in fire size, area burned, and fire frequency over the past several decades remain well below historical tribally-influenced frequency and extent of burning in California (Stephens et al. 2007)
• No significant trends in the average areal proportion of high-severity fire were documented in northwestern CA from 1984–2008 (Parks et al. 2015; Law & Waring 2015; Keyser & Westerling 2017)
  ○ The relatively short period of record for fire severity data may obscure long-term trends
	Projected future trends:
	• State-wide, up to 77% increase in mean annual area burned and 50% increase in the frequency of extremely large fires (>10,000 ha) by 2100 (Westerling 2018)
	  ○ Less significant increases or possible decrease along the North Coast (Westerling et al. 2011)
	• Little projected change in fire severity in northwestern California by 2050 in models based solely on historical fire-climate relationships (Parks et al. 2016)
	  ○ However, human activity and fuel buildup from decades of fire suppression have altered historical fire-climate relationships

[7] Although it is a natural process, woody vegetation encroachment (i.e. natural succession to woody climax communities) is considered a threat in the context of this assessment because it can lead to overall loss of coastal scrub area.

Regional Wildfire Trends	
○ To date, there are no peer-reviewed studies on trends in northern California fire severity that include data from the last ten years	(Taylor et al. 2016; Syphard et al. 2017; Wahl et al. 2019), and projections that incorporate these factors suggest that more significant increases in fire severity and size may occur (Mann et al. 2016; Wahl et al. 2019) • The majority of impacts to natural and human ecosystems come from extreme fire events (i.e., fires that have a low probability of occurring in any given place and time), which are likely to increase over the coming century (Westerling 2018) ○ Generally, these patterns are not well-represented in studies that evaluate indices of mean fire size, intensity/severity, etc.
Summary of Potential Impacts on Habitat *(see text for citations)*	
• Increased plant species richness with cultural burning or increased frequency of wildfire • Increased tree encroachment with fire exclusion or less frequent wildfire • During periods of low precipitation, high-intensity fires may occur in areas of woody fuel accumulation	

Sensitivity and current exposure to non-climate stressors

Regional experts evaluated coastal bluffs and scrub as having moderate-high sensitivity to non-climate stressors (low confidence in evaluation), with an overall moderate current exposure to these stressors within the study region (low confidence). Key non-climate stressors that affect coastal bluffs and scrub include invasive species, roads/highways/trails, fire suppression, residential and commercial development, and livestock grazing.[8]

<u>Invasive species</u>

Invasive plant species (e.g., iceplant) inhibit growth, increase competition, and reduce species richness for native grasses and shrubs in coastal bluffs and scrub habitats (D'Antonio & Mahall 1991; Alvarez & Cushman 2002; Ford & Hayes 2007). Cape ivy (*Delairea odorata*) also commonly invades coastal bluffs and scrub in southern Humboldt County and Mendocino County within the study area (Robison & DiTomaso 2010), reducing species richness, diversity, and seedling abundance by monopolizing light, water, and soil nutrients (Alvarez & Cushman 2002). This non-native perennial has multiple life history characteristics that allow it to outcompete native and non-native species, including rapid growth, clonal reproduction, and ability to tolerate both drought and freezing conditions (Alvarez & Cushman 2002). Increasing

[8] Non-climate stressors presented are those ranked as having a moderate or higher impact on this habitat type; additional non-climate stressors that may influence the habitat to a lesser degree include agriculture, pollution, and recreation.

temperatures and changing precipitation regimes may also encourage drought-tolerant invasive plant species from southern coastal scrub communities to expand their range into northern California, potentially outcompeting native coastal vegetation in some areas (Cornwell et al. 2012). Invasive plants associated with disturbance and residential landscaping can threaten the abundance and diversity of native flora and fauna in more heavily developed coastal bluff and scrub areas (Ford & Hayes 2007).

Roads, highways, and trails

The impacts of roads, highways, and trails on coastal bluffs and scrub are widespread in coastal northern California, especially in the Intertribal Sinkyone Wilderness Area in Mendocino County; Petrolia and Table Bluff in Humboldt County; and Point St. George in Del Norte County (Vuln. Assessment Workshop, pers. comm., 2017; Vuln. Assessment Reviewer, pers. comm., 2018). Roads, highways, and trails can reduce habitat extent, inhibit native plant seed dispersal, and constrain wildlife movement, altering species composition and hindering habitat recovery following disturbance (Trombulak & Frissell 2000; Coffin 2007; Vuln. Assessment Workshop, pers. comm., 2017). Additionally, transportation corridors facilitate invasive plant spread (especially non-native annual grasses; Harrison et al. 2002), both during road construction that disturbs soils and through increasing exotic seed transport on vehicles (Coffin 2007). Roads may also introduce heavy metals (e.g., lead), salts, and nutrients into roadside areas through runoff and can alter soil density, temperature, and water content (Trombulak & Frissell 2000).

Fire suppression

Fire exclusion has significantly affected the structure and function of coastal bluff/scrub communities and reduced species richness, particularly in and around the wildland-urban interface (Ford & Hayes 2007; Vuln. Assessment Workshop pers. comm., 2017). In coastal bluff and scrub communities, fire exclusion has resulted in encroachment of California bay and other tree species into areas of mature coyote brush or other shrubs (Williams & Hobbs 1989; Steinberg 2002; Smither-Kopperl 2016), while also promoting the expansion of coastal bluff/scrub species (e.g., coyote brush) into adjacent grasslands (McBride & Heady 1968). The impact of fire suppression is notable in the Table Bluff area, where standing dead hairy manzanita (*Arctostaphylos columbiana*) and California hazelnut can be found in a Sitka spruce (*Picea sitchensis*) forest, illustrating how scrubland vegetation types can be converted to forest in the absence of fire (Vuln. Assessment Reviewer, pers. comm., 2018). It is likely that fire suppression also results in greater accumulation of woody fuel, which may increase the risk of high-intensity fires during periods of dry weather (Ford & Hayes 2007). Fire suppression has also led to reduced extent of early successional plant communities and reduced productivity of shrub species that are important for resource-gathering by northern California tribes (Anderson 2005; Vuln. Assessment Reviewer, pers. comm., 2018).

Residential and commercial development

Development on marine terraces adjacent to the ocean has been extensive in northern California (Griggs & Patsch 2004; Ford & Hayes 2007), especially in the Fort Bragg and Mendocino areas (Vuln. Assessment Workshop, pers. comm., 2017). As a result, large areas of coastal bluffs and scrub have been lost, degraded, and/or fragmented, and this habitat type is continuing to decline in extent due to the ongoing expansion of developed areas (Ford & Hayes 2007). Development introduces physical barriers to habitat migration and movement of wildlife (Ford & Hayes 2007; Vuln. Assessment Workshop, pers. comm., 2017), increases predation by domestic and feral pets, and introduces invasive plants that threaten the abundance and diversity of native flora and fauna (Ford & Hayes 2007). Additionally, coastal armoring may subject adjacent bluffs adjacent to developed areas to increased wave energy and subsequent erosion as protective beaches are depleted of sediment (Griggs & Patsch 2004; Griggs 2005; Hapke & Reid 2007). Stormwater runoff from culverts and drains in urban areas also concentrate runoff in bluff areas, increasing erosion and the likelihood of bluff failure (Griggs & Patsch 2004; Griggs & Russell 2012)

Livestock grazing

Carefully managed grazing can act as a disturbance that helps maintain coastal bluff and scrub integrity and extent (Elliott & Wehausen 1974; Ford & Hayes 2007), especially when combined with periodic burning (de Becker 1988). Managed grazing allows the coastal scrub plant community to persist in a dynamic equilibrium with grasslands, with scrub patches dying out and new ones becoming established (Davison & Barbour 1977). In addition, grazing benefits habitat for the federally endangered western lily (*Lilium occidentale*) along coastal bluff/scrub, prairie, and forest edges (Imper 1988). Conversely, overgrazing can severely degrade coastal bluffs and scrub (Ford & Hayes 2007) by shortening plants and reducing plant species richness (Hayes & Holl 2003; Ford & Hayes 2007; Vuln. Assessment Workshop, pers. comm., 2017) and by favoring short, unpalatable species (e.g., prickly coyote thistle [*Eryngium armatum*]) and annual grasses over native perennials (Elliott & Wehausen 1974; Hayes & Holl 2003; Ford & Hayes 2007). Under intense grazing pressure, coastal scrub can be replaced by grasslands (Davison & Barbour 1977).

Adaptive Capacity

Coastal bluffs and scrub were evaluated by regional experts as having low-moderate overall adaptive capacity (moderate confidence in evaluation).

Habitat extent, integrity, continuity, and permeability

Regional experts evaluated coastal bluffs and scrub as having a low-moderate geographic extent (high confidence in evaluation), low-moderate structural and functional integrity (moderate confidence), and low continuity (moderate confidence).

Landscape permeability for coastal bluffs and scrub was evaluated as low-moderate (moderate confidence). Land-use conversion and invasive species were identified as the primary barriers to habitat continuity and dispersal across the study region.[9]

Coastal bluff and scrub habitats extend from the Oregon coast south to Monterey County, occurring patchily in Humboldt and Mendocino Counties (Ford & Hayes 2007). Historically, coastal bluffs and scrub may have been more widespread on marine terraces than it is today, with conifer and oak-bay woodlands colonizing areas farther inland and northern coastal bluffs and scrub occurring on the more wind-exposed, salt-laden areas near the coast, or as seral habitat patches growing in areas of landslides or burns (Ford & Hayes 2007). Although some areas of coastal bluffs and scrub remain intact (e.g., Sinkyone Wilderness, King Range National Recreation Area; Vuln. Assessment Reviewer, pers. comm., 2018), residential and commercial development has eliminated, fragmented, or degraded much of this habitat type in northern California (Stromberg et al. 2002; Ford & Hayes 2007). Lack of grazing and less frequent fire has allowed some coastal scrub vegetation to expand into the wildland–urban interface (Ford & Hayes 2007). Road cuts and landslides provide additional opportunities for expansion of patchy, low-diversity coastal scrub into newly disturbed areas (Harrison et al. 1971; Malanson & O'Leary 1982). Despite the expansion of some component species into adjacent habitats, the overall extent of structurally diverse, species-rich scrub is decreasing, primarily due to development and a lack of disturbance (e.g., fire, grazing) that allows conversion to woodland habitat (Ford & Hayes 2007).

Habitat diversity

Regional experts evaluated coastal bluffs and scrub as having low-moderate physical and topographical diversity (low confidence in evaluation), moderate-high component species diversity (moderate confidence), and low functional diversity (low confidence).

Northern coastal scrub communities range from a patchy cover of nearly prostrate shrubs adjacent to the ocean to areas with a denser, more continuous overstory of shrubs up to 2 m (6.6 ft) high with a perennial herbaceous understory (de Becker 1988). Species composition varies depending on differing exposure to wind, sea salt, fog, and solar radiation (Wiedemann 1984; Baxter & Parker 1999; Wrubel & Parker 2018). Plant community composition also changes along the coast from north to south, with increasingly xeric conditions shifting dominance from evergreen species in the north to drought-deciduous species in the south (de Becker 1988). Coastal scrub vegetation in northern California is characterized by flexible stems and foliage, while southern coastal scrub and chaparral typically has stiffer foliage (Ford & Hayes 2007). High-quality coastal scrub that includes diverse assemblages of mature shrubs, native grasses, and forbs are more common in northern than southern California (CNPS 2019).

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[9] Barriers presented are those ranked as having a moderate or higher impact on this habitat type; additional barriers that may limit habitat continuity and dispersal to a lesser degree include agriculture and roads/highways/trails.

Northern coastal bluff/scrub plant communities are typically dominated by shrubs, forbs, and grasses, including coyote brush, sword fern (*Polystichum munitum*), salal (*Gaultheria shallon*), thimbleberry, salmonberry, blueblossom (*Ceanothus thyrsiflorus*), cascara (*Frangula purshiana*), California hazelnut, wax myrtle (*Morella californica*), western azalea (*Rhododendron occidentale*), dune willow (*Salix hookeriana*), Pacific reed grass (*Calamagrostis nutkaensis*), tufted hair grass (*Deschampsia cespitosa*), red fescue (*Festuca rubra*), and oat grass (*Danthonia californica*; CNPS 2019). Depending on disturbance and land use history, among other factors, coastal shrub stands can represent a variety of successional stages; some mature into shrub-dominated habitat, while others transition to forests comprising species such as Bishop pine (*Pinus muricata*), Douglas-fir (*Pseudotsuga menziesii*), California bay, and Sitka spruce (McBride 1974; Grams et al. 1977; Heady 1977; Ford & Hayes 2007). Coastal bluffs and scrub also supports federally and state endangered plant species such as western lily (Calflora 2019), as well as components of natural communities identified as sensitive by California natural resource agencies (e.g., hazelnut scrub, coastal bramble, and Pacific reed grass meadows, among others; CNPS 2019). These vegetation types also have cultural significance for northern California tribes (Vuln. Assessment Reviewer, pers. comm., 2018).

Coastal scrub vegetation provides important habitat for a variety of wildlife, including mammals, birds, amphibians, and insects (CDFW 2015; Smither-Kopperl 2016). In addition to providing food and cover for rabbits and other small mammals (Steinberg 2002), coastal bluffs and scrub harbors less common mammals, such as the pallid bat (*Antrozous pallidus*), the western spotted skunk (*Spilogale gracilis*), and the federally-listed Port Arena mountain beaver (*Aplodontia rufa nigra*, found only in Mendocino County; Steele & Litman 1998; California Department of Fish and Wildlife 2015). Many migratory and resident birds forage for insects, berries, and other food items in this habitat, including the white-tailed kite (*Elanus leucurus*), Bryant's savannah sparrow *Passerculus sandwichensis alaudinus*), peregrine falcon (*Falco peregrinus*), and the federally- and state-listed western snowy plover (*Charadrius nivosus nivosus*; California Department of Fish and Wildlife 2015). Rare amphibians in this habitat include the western spadefoot toad (*Spea hammondii*), the federally listed California red-legged frog (*Rana draytonii*), the state-listed foothill yellow-legged frog (*Rana boylii*; California Department of Fish and Wildlife 2015), and many salamanders considered Species of Special Concern in California (Vuln. Assessment Reviewer, pers. comm., 2018). In addition, coastal bluff and scrub vegetation supports high levels of insect diversity, including ants, bees, and parasitic wasps, especially in late September and early October (Smither-Kopperl 2016). Other key pollinators in coastal bluffs and scrub include federally-listed butterfly species, such as the Oregon silverspot butterfly (*Speyeria zerene hippolyta*), Behren's silverspot butterfly (*Speyeria zerene behrensii*), and lotis blue butterfly (*Lycaeides argyrognomon lotis;* Vuln. Assessment Reviewer, pers. comm., 2018).

Resistance and recovery

Regional experts evaluated coastal bluffs and scrub as having low resistance to climate stressors and natural disturbance regimes (moderate confidence in evaluation). Recovery potential was evaluated as low (moderate confidence).

Coastal bluff and scrub vegetation thrives in a high-disturbance environment through adaptations such as succulent or hairy leaves, long roots and stolons that stabilize plants on shifting sands, and the ability to colonize relatively unstable and sterile substrates after bluff erosion (Thorne et al. 2016). These traits allow most coastal scrub species to recover quickly from natural disturbances and expand into newly-disturbed surrounding areas (Heady et al. 1988; Steinberg 2002; Ford & Hayes 2007). For example, coyote brush colonizes actively eroding areas, where exposed mineral soil gives coyote brush an advantage over perennial grasses and chaparral shrubs (Kirkpatrick & Hutchinson 1980; Steinberg 2002).

Several common coastal shrubs found in this habitat, including coyote brush, California coffeeberry (*Frangula californica*), and western poison oak (*Toxicodendron diversilobum*), resprout readily even after extremely severe, high-intensity fires (McBride & Heady 1968; Ford 1991; Steinberg 2002). Additionally, coyote brush produces large numbers of wind-dispersed seeds that germinate easily on a variety of soil types, allowing the species to quickly colonize burned areas (Steinberg 2002). While non-sprouting shrubs (e.g., blueblossom) and native perennial herbs (e.g., seaside woolly sunflower; [*Eriophyllum staechadifolium*]) are more likely to experience mortality during even low- and moderate-severity fires, they are able to regenerate from seeds in the soil seed bank (Ford 1991; David & Parker 1997; Ford & Hayes 2007). Sticky monkey flower (*Diplacus aurantiacus*), which can grow from either sprouts or seeds, exhibits a post-fire regeneration pattern similar to that of the obligate seeders (Ford 1991).

Most northern coastal scrub plant species have some drought-avoidance traits that allow them to survive the dry summer months typical of a Mediterranean climate (Mooney & Dunn 1970). Evergreen species (e.g., coyote brush, California coffeeberry) lose less water during periods of drought compared to deciduous species and also require less energy annually for foliage production (Mooney & Dunn 1970). In addition, coyote brush and several other shrub species develop a long taproot (up 3 m [10 ft]) that allows them to access moisture deeper within the soil (Steinberg 2002; Smither-Kopperl 2016), and coyote brush also utilizes fog water to ameliorate drought impacts during the late summer (Emery et al. 2018). Conversely, annual species, especially non-native grasses, are likely to be negatively affected by drought given their shallower root system and annual life cycle (Adler & Levine 2007; Cleland et al. 2013; Harrison et al. 2015; Copeland et al. 2016).

Management potential

Public and societal value

Regional experts evaluated coastal bluffs and scrub as having moderate-high public and societal value (moderate confidence in evaluation).

Extensive management of coastal bluffs and scrub by northern California tribes supported its persistence until Euro-American settlement around 1850 (Gordon 1974; Anderson 1993; Ford & Hayes 2007), highlighting the importance of this habitat to the spiritual and material culture of northern California tribes (Sloan & Hostler 2014). The general public also values coastal areas for services such as aesthetics and recreation; however, they often have limited understanding of the value of this habitat type in supporting species diversity and protecting adjacent habitats and communities from erosion (Ford & Hayes 2007). Additionally, some segments of the public may have concerns about the risk of using prescribed burning for vegetation management in this habitat (Ford & Hayes 2007; Vuln. Assessment Workshop, pers. comm., 2017). However, there is growing recognition that mature, structurally diverse occurrences of coastal bluff/scrub are increasingly rare and worth preserving (Ford & Hayes 2007; Wrubel & Parker 2018).

Management capacity and ability to alleviate impacts[10]

Regional experts evaluated the potential for reducing climate impacts on coastal bluffs and scrub through management as moderate (low confidence in evaluation). Regional experts identified the primary use conflicts and/or competing interests for coastal bluff/scrub habitats as development and recreation (Vuln. Assessment Workshop, pers. comm., 2017).

There are multiple opportunities to help protect and restore high-quality coastal bluffs and scrub, including managing anthropogenic disturbance regimes, selectively replanting native plant species, and planning for inland habitat retreat (Griggs & Patsch 2004; Ford & Hayes 2007; Thorne et al. 2009; Hanak & Moreno 2012; Wrubel & Parker 2018). Prescribed burning, manual removal of trees, and carefully managed grazing may help promote growth of key native plant species and reduce tree encroachment in high-quality habitat areas (Ford & Hayes 2007; Wrubel & Parker 2018; Vuln. Assessment Reviewer, pers. comm., 2018). For revegetation of degraded habitat sites, use of plant taxa and seeds from nearby sites with similar topographic exposure, in conjunction with remediation of any soil disturbance, may increase the success of habitat restoration efforts (Wrubel & Parker 2018).

At the landscape scale, there are additional options for transportation and development planning to reduce impacts on coastal bluffs and scrub (Griggs & Patsch 2004; Thorne et al. 2009; Hanak & Moreno 2012). For instance, natural resource management agencies and transportation planners can access a planning tool for mitigating impacts from road construction projects in California, including site-specific information on coastal scrub (Thorne et al. 2009). Additionally, the use of development setbacks may slow erosion of coastal bluffs by siting new construction projects at a predetermined distance from the bluff edge and eliminating the need for additional coastal armoring (e.g., seawalls, jetties, revetments) to protect buildings (Griggs & Patsch 2004; Hanak & Moreno 2012).

Ecosystem services

Coastal bluffs and scrub provide a variety of ecosystem services, including:

- Provisioning of food, fiber, genetic resources, natural medicines, and ornamental resources;

[10] Further information on climate adaptation strategies and actions for northern California can be found on the project page (https://bit.ly/31AUGs5).

- Regulation of air quality, flood/erosion control, pollination, and natural hazard regulation;
- Support of oxygen production and soil formation/retention; and
- Social/cultural/tribal uses for spiritual/religious purposes, knowledge systems, educational values, aesthetic values, social relations, sense of place, viewshed, cultural heritage, inspiration, and recreation (Norgaard 2014; Sloan & Hostler 2014; Norgaard et al. 2016; Vuln. Assessment Workshop, pers. comm. 2017).

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Further information on the Northern California Climate Adaptation Project is available on the project website (https://tinyurl.com/NorCalAdaptation).

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Northern California Climate Adaptation Project:

Vulnerability Assessment Methods and Application

Defining Terms

Exposure: A measure of how much of a change in climate or climate-driven factors a resource is likely to experience (Glick et al. 2011).

Sensitivity: A measure of whether and how a resource is likely to be affected by a given change in climate or factors driven by climate (Glick et al. 2011).

Adaptive Capacity: The ability of a resource to accommodate or cope with climate change impacts with minimal disruption (Glick et al. 2011).

Vulnerability: A function of the sensitivity of a particular resource to climate changes, its exposure to those changes, and its capacity to adapt to those changes (IPCC 2007).

Vulnerability Assessment Model

The vulnerability assessment model applied in this process was developed by EcoAdapt (EcoAdapt 2014a; EcoAdapt 2014b; Kershner 2014; Hutto et al. 2015; Gregg 2018),[11] and includes evaluations of relative vulnerability by local and regional stakeholders who have detailed knowledge about and/or expertise in the ecology, management, and threats to focal habitats, species groups, individual species, and the ecosystem services that these resources provide. Stakeholders evaluated vulnerability for each resource by discussing and answering a series of questions for sensitivity and adaptive capacity. Exposure was evaluated by EcoAdapt using projected future climate changes from the scientific literature. Each vulnerability component (i.e., sensitivity, adaptive capacity, and exposure) was divided into specific elements. For example, habitats included three elements for assessing sensitivity and six elements for adaptive capacity. Elements for each vulnerability component are described in more detail below.

In-person workshops were held in Eureka, Redding, and Upper Lake between May and October 2017. Participants self-selected habitat and species group/species breakout groups and evaluated the vulnerability of each resource. Participants were first asked to describe the habitat and/or to list the species to be considered in the evaluation of an overarching species group. Due to limitations in workshop time and participant expertise, multiple resources were not assessed during these engagements. Evaluations for remaining habitats, species groups, and species were completed by contacting resource experts.[12]

[11] Sensitivity and adaptive capacity elements were informed by Lawler 2010, Glick et al. 2011, and Manomet Center for Conservation Sciences 2012.

[12] Resources evaluated by experts included: coastal bluff/scrub habitats, coastal conifer hardwood forest, true fir forest, lakes/ponds, freshwater marshes, vernal pools, seeps/springs, native insect pollinators, native ungulates, salamanders, frogs, native mussels, marbled murrelet, and northwestern pond turtle.

Stakeholders assigned one of five rankings (High, Moderate-High, Moderate, Low-Moderate, or Low) for sensitivity and adaptive capacity. EcoAdapt assigned rankings for projected future climate exposure. Rankings for each component were then converted into scores (High-5, Moderate-High-4, Moderate-3, Low-Moderate-2, or Low-1), and the scores were averaged (mean) to generate an overall score. For example, scores for each element of habitat sensitivity were averaged to generate an overall habitat sensitivity score. Scores for exposure were weighted less than scores for sensitivity and adaptive capacity because the uncertainty about the magnitude and rate of future change is greater. Sensitivity, adaptive capacity, and exposure scores were combined into an overall vulnerability score calculated as:

Vulnerability = [(Climate Exposure*0.5) x Sensitivity] - Adaptive Capacity

Elements for each component of vulnerability were also assigned one of three confidence rankings (High, Moderate, or Low). Confidence rankings were converted into scores (High-3, Moderate-2, or Low-1) and the scores averaged (mean) to generate an overall confidence score. These approximate confidence levels were based on the Manomet Center for Conservation Sciences (2012) 3-category scale, which collapsed the 5-category scale developed by Moss and Schneider (2000) for the IPCC Third Assessment Report. The vulnerability assessment model applied here assesses the confidence associated with individual element rankings and, from these rankings, estimates the overall level of confidence for each component of vulnerability and then for overall vulnerability.

Stakeholders and decision-makers can consider the rankings and scores presented as measures of relative vulnerability and confidence to compare the level of vulnerability among the focal resources evaluated in this project. Elements that received lower confidence rankings indicate knowledge gaps that applied scientific research could help address.

Vulnerability Assessment Model Elements

Sensitivity & Exposure (Applies to Habitats, Species Groups, Species)

- **Climate and Climate-Driven Factors:** e.g., air temperature, precipitation, freshwater temperature, soil moisture, snowpack, extreme events: drought, altered streamflows, etc.
- **Disturbance Regimes:** e.g., wildfire, flooding, drought, insect and disease outbreaks, wind
- **Future Climate Exposure:** e.g., consideration of projected future climate changes (e.g., temperature and precipitation) as well as climate-driven changes (e.g., altered fire regimes, altered water flow regimes, shifts in vegetation types)
- **Stressors Not Related to Climate:** e.g., tectonic and volcanic events; residential or commercial development; agriculture and/or aquaculture; roads, highways, trails; dams and water diversions; invasive and other problematic species; livestock grazing; fire suppression; timber harvest; mining; etc.

Sensitivity & Exposure (Applies to Species Groups and Species)

- **Dependencies:** e.g., dependencies on sensitive habitats, specific prey or forage species, and the timing of the appearance of these prey and forage species (concern for mismatch)

Sensitivity & Exposure (Applies to Species ONLY)

- **Life History:** e.g., species reproductive strategy, average length of time to reproductive maturity

Adaptive Capacity (Applies to Habitats, Species Groups, Species)

- **Extent, Integrity, and Continuity/Connectivity:** e.g., resources that are widespread vs. limited, structural and functional integrity (e.g., degraded or pristine) of a habitat or health and functional integrity of species (e.g., endangered), isolated vs. continuous distribution
- **Landscape Permeability:** e.g., barriers to dispersal and/or continuity (e.g., land-use conversion, energy production, roads, timber harvest, etc.)
- **Resistance and Recovery:** e.g., *resistance* refers to the stasis of a resource in the face of change, *recovery* refers to the ability to "bounce back" more quickly from the impact of stressors once they occur
- **Management Potential:** e.g., ability to alter the adaptive capacity and resilience of a resource to climatic and non-climate stressors (societal value, ability to alleviate impacts, capacity to cope with impacts)
- **Ecosystem Services:** e.g., provisioning, regulating, supporting, and/or cultural services that a resource produces for human well-being

Adaptive Capacity (Applies to Habitats ONLY)

- **Habitat Diversity:** e.g., diversity of physical/topographical characteristics, component native species and functional groups

Adaptive Capacity (Applies to Species Groups, Species)

- **Dispersal Ability**: i.e., ability of a species to shift its distribution across the landscape as the climate changes
- **Intraspecific/Life History Diversity:** e.g., life history diversity, genetic diversity, phenotypic and behavioral plasticity

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