Beaches and Dunes[1]

Executive Summary

Beaches and Dunes	Score	Confidence
Sensitivity	4 Moderate-High	3 High
Exposure	5 High	3 High
Adaptive Capacity	3 Moderate	3 High
Vulnerability	4 Moderate-High	3 High

Beach and dune systems are formed from unconsolidated sand from coastal bluffs and watersheds, are shaped by a myriad of marine and terrestrial processes, and provide habitat for a variety of species, including pinnipeds, sea and shorebirds, and unique vegetation. Key climate sensitivities identified for this habitat by workshop participants include sea level rise, coastal erosion, wave action, and sediment supply and movement. Key non-climate sensitivities include coastal armoring and road construction, overwater/underwater structures, recreation, invasive species, and dredging. Beach and dune habitats are transcontinental in geographic extent, have moderate habitat connectivity, and have moderate structural and functional integrity due to impacts from coastal, inland, and watershed development. Beach and dune habitats have relatively low-moderate physical/topographical and functional group diversity, but moderate component species diversity, and feature key species such as sand crabs and talitrid amphipods. Overall, beach and dune habitats are highly valued and can recover quickly if they have space to migrate or have enough sediment supply to keep up with sea level rise and erosion. Potential management measures include beach nourishment and protection of retreat areas.

Sensitivity

I. Sensitivities to climate and climate-driven factors

Climate and climate-driven changes identified (score[2], confidence[3]): sea level rise (5, high), wave action (5, high), coastal erosion (5, high), sediment supply and movement (5, high), wind (3, high), precipitation (2, moderate), pH (1, low)

Climate and climate-driven changes that may benefit the habitat: coastal erosion

- Description of benefits: Increased erosion of coastal cliffs and inland areas may prove beneficial to some beaches by increasing supplies of sediment that enable sediment deposition rates to keep up with rates of sea level rise.

Overall habitat sensitivity to climate and climate-driven factors: High

- Confidence of workshop participants: High

Additional participant comments

Beaches and dunes are naturally very dynamic systems; if given room to migrate, they are likely to be resilient to climate and climate-driven changes, though much of their overall areal habitat extent might be lost

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[1] Refer to the introductory content of the results section for an explanation of the format, layout and content of this summary report.

[2] For scoring methodology, see methods section. Factors were scored on a scale of 1-5, with 5 indicating high sensitivity and 1 indicating low sensitivity.

[3] Confidence level indicated by workshop participants.

Supporting literature

Beach and dune systems are formed from unconsolidated sand from coastal bluffs and watersheds, and are shaped by a myriad of marine and terrestrial processes (Largier et al. 2010). Literature review was conducted for those factors scoring 4 or higher, although the other sensitivities identified should also be considered.

Sea Level Rise

Sea level rise can inundate current beach and dune systems and increase rates of shoreline erosion, potentially forcing upland retreat of beach and dune habitats (Feagin et al. 2005). Where development or other barriers (i.e., cliffs) block upland retreat, beach and dune habitats could suffer reduced areal extent and/or increased fragmentation, shifting from continuous habitat to narrower, steeper, and isolated pocket beaches (Largier et al. 2010). Reductions in beach and dune habitat could affect many species, including pinnipeds (e.g., elephant seals, harbor seals, sea lions) and nesting shore birds (e.g., western snowy plover). In addition, sea level rise can contribute to changes in relative proportions of the different ecological zones within beach habitats, which could lead to propagating changes in all levels of the food web (Dugan et al. 2008). Sea level rise can also disrupt successional dynamics and degrade habitat quality by preventing the formation of mature coastal dune vegetation communities (Feagin et al. 2005).

Wave Action

Wave action, which varies seasonally and according to local and more broad scale climatic processes, shapes beach and dune systems, contributes to erosion, and affects key species. Wave heights in winter can be in excess of 8 m and are driven by extra-tropical cyclones in the North Pacific, smaller, shorter period waves in summer are generated from winds stemming from the North Pacific High (Wingfield and Storlazzi 2007), and local winds affect wave heights throughout the year. Waves, particularly larger wave heights associated with late winter El Niño events, are often the main driver of beach and dune erosion, as these large, late winter waves coincide with when beaches are at their narrowest widths (Storlazzi and Griggs 2000; Wingfield and Storlazzi 2007). Waves can also increase coastal flooding (Storlazzi and Griggs 2000; Wingfield and Storlazzi 2007), potentially inundating dune and beach areas and forcing landward retreat of these habitats (Feagin et al. 2005). Waves can also shift distributions of sandy shorelines. For example, shifts in the Pacific Decadal Oscillation (PDO) can alter wave directions, exposing sheltered beaches to significant erosion and/or rotating sandy shoreline segments to the north and increasing erosion in southern ends of littoral cells (Sallenger et al. 2002). In addition, intense wave action during storms or larger wave heights coinciding with high tides can negatively affect key species such as sand crabs and talitrid amphipods, impacting larger food webs (Dugan et al. 2008) and nutrient cycling (Lastra et al. 2008).

Coastal Erosion

Coastal erosion can have varying impacts on beach and dune systems. For example, beach erosion combined with sea level rise can reduce beach and dune habitat, especially in areas where beaches are backed by coastal cliffs (i.e., a majority of beaches in the study area) (Largier et al. 2010). Reduction of beach and dune habitat can negatively impact component species such as sand crabs and wrack consumers, as well as species that depend on beach habitats for breeding and nesting (i.e., pinnipeds and seabirds) (Largier et al. 2010). Alternatively, erosion of coastal cliffs may help some beach and dune systems keep pace with sea level rise by increasing local sediment delivery and enhancing sandy beach habitat (Sarah Allen, pers. comm., 2014). In

addition, erosion of upland or inland sediments can increase sediment transport and delivery to beach and dune areas (Sarah Allen, pers. comm., 2014).

Sediment Supply and Movement

Sediment supply and movement influences the areal extent of beach and dune systems, and is controlled by a variety of climate and climate-driven factors (i.e., wave action, coastal erosion, currents, precipitation), as well as by changes within the "sediment-shed" (i.e., changes in the watershed, coastal wetlands, or the littoral cell) (Revell et al. 2007; Largier et al. 2010; Vulnerability Assessment Workshop, pers. comm., 2014). Surpluses in local sediment budgets typically increase beach width and minimize shoreline erosion, while sediment deficits result in narrower beaches with significant rates of coastal erosion (Largier et al. 2010). Reductions in beach width can also expose dune habitats to increased wave exposure (Largier et al. 2010). Sediment supply will vary according to many factors. For example, short, heavy precipitation events can increase freshwater sediment discharge and bolster beach and dune systems, though this dynamic is mediated by inland water and sediment retention structures such as dams (Slagel and Griggs 2008; Largier et al. 2010). Alternatively, wave action can deliver or remove sediment, leading to dynamic changes in beach shape and size over the course of different seasons.

Beaches and dunes are also sensitive to precipitation and pH, but to a lesser extent than the afore-mentioned factors. For example, pH can affect sand crab shell formation and the foraging value of beach and dune habitat (Vulnerability Assessment Workshop, pers. comm., 2014), while precipitation and subsequent runoff can increase sediment delivery to beach and dune systems and/or contribute to shifting soil salinities in dune vegetation communities (Williams et al. 1999; Greaver and Sternberg 2007).

II. Sensitivities to disturbance regimes

Disturbance regimes identified: wind and storms

Overall habitat sensitivity to disturbance regimes: High

- Confidence of workshop participants: High

Additional participant comments

Wind, influenced by air and sea surface temperatures, affects sediment supply and movement, periodically adding, removing, and repositioning sand within beach and dune systems. Storms affect wave height, influence rates of erosion, and can alter sediment supply.

Supporting literature

Winds are typically stronger in spring and summer and weaker in fall and winter (Largier et al. 2010). Alongshore winds increased from 1940-1990 (Bakun 1990; Schwing and Mendelssohn 1997; Mendelssohn and Schwing 2002), and are expected to increase in all seasons in the future, particularly in summer and fall, due to increasing differences in land-ocean pressures and temperatures (Snyder et al. 2003; Auad et al. 2006; Largier et al. 2010). In addition to the impacts mentioned by workshop participants, winds may impact the delivery of cold, nutrient-rich water to beach habitat, impacting the availability of food for suspension feeders (Dan Robinette, pers. comm., 2014). Storms are typically more common in winter, and can vary in

intensity, magnitude, and direction according to larger climate forcings such as the El Niño Southern Oscillation (ENSO) or the Pacific Decadal Oscillation.

III. Sensitivity and current exposure to non-climate stressors

Non-climate stressors identified (score[4], confidence[5]): coastal roads/armoring (5, high), overwater/underwater structures (4, high), recreation (3, high), invasive species (3, moderate), dredging (3, moderate)

Overall habitat sensitivity to non-climate stressors: Moderate-High

- Confidence of workshop participants: High

Overall habitat exposure to non-climate stressors: Moderate

- Confidence of workshop participants: High

Additional participant comments

Shifting water storage demands could affect dam operations in the future, with further impacts on sediment delivery to beach and dune habitats. Recreation can have direct impacts on beach and dune systems, but is also a critical factor in maintaining stewardship support. Invasive and problem species outcompete native dune vegetation, can lock up foredune sand supply, and prevent upland migration of this system. Dredging can influence sediment supply for beach and dune systems by reducing supply if dredged sediment is disposed of outside the littoral cell, which can increase beach and dune sensitivity to climate changes. Alternatively, dredged materials can be used for beach nourishment, which could bolster beach and dune resilience (e.g., by offsetting erosion), though also negatively impact the infaunal community.

Supporting literature

Armoring/Roads

Coastal armoring and road construction prevent upland beach and dune migration in response to sea level rise and increased passive erosion, increasing the sensitivity of beach and dune systems. Passive erosion related to armoring or road structures can shift habitat zones downward on the beach profile by "drowning" upper beach areas, disproportionally degrading upper and mid beach habitat (Dugan et al. 2008). These effects will only become more pronounced with sea level rise as these structures interact with waves and tides (Dugan et al. 2008). In addition, armoring can replace beach habitat, reducing beach extent and negatively impacting bird species (Dugan et al. 2008). Armoring is projected to increase, although beach nourishment is now being used more frequently as an alternative (Defeo et al. 2009).

Overwater/Underwater Structures

Overwater and underwater structures can alter sediment supply and delivery and impair the resiliency of beach and dune habitats. Dams and debris basins in watersheds can trap sediments and alter peak flows, effectively reducing sediment transport to beach and dune systems which increases littoral cell sediment deficits and the potential for erosion (Willis and Griggs 2003; Slagel and Griggs 2008; Largier et al. 2010). For example, multiple dam projects on the Russian

[4] For scoring methodology, see methods section. Factors were scored on a scale of 1-5, with 5 indicating high sensitivity and 1 indicating low sensitivity.
[5] Confidence level indicated by workshop participants.

River reduced annual coarse-grained sediment supplies by more than 30% (Slagel and Griggs 2008).

Recreation

Recreational use can lead to trampling of vegetation or sensitive habitat areas, as well as to behavioral modifications in beach and dune wildlife (e.g., bird nest abandonment and seal beach abandonment) (Grigg et al. 2002; Schlacher et al. 2007; Largier et al. 2010). The accumulation of plastics and other human trash as a result of recreation and use can negatively impact beach and dune systems through direct impacts to species (entanglement, ingestion, smothering) and indirect impacts to the habitat itself (clean-up efforts and introduction of invasive species) (EPA 2012). Coastal recreational pressure could increase as a result of population growth and increased inland temperatures (Vulnerability Assessment Workshop, pers. comm., 2014).

Invasive and problem species

Many dunes have been invaded by European beachgrass (*Ammophilia arenaria*), resulting in reduced species richness (Barbour et al. 1976), changes in dune shape and orientation relative to the ocean (Barbour and Johnson 1988), and degradation of the habitats that back dunes, such as swales (Randall and Hoshovosky 2000). Iceplant/hottentot fig (*Carpobrotus edulis*), another harmful non-native plant, creates deep mats that exclude native vegetation (California State Parks 2009). Additionally, non-native species such as the sea fig (*Carpobrotus chilensis*) and the Uruguayan pampas grass (*Cortaderia selloana*) could also negatively impact dune systems in the study region (ONMS 2014). Non-invasive, problem species, such as gulls, ravens, foxes, coyotes, dogs, feral cats, skunks and racoons often follow human activity into beach and dune habitat, negatively impacting shorebird species, such as the snowy plover, and altering ecological dynamics (Campbell 2013; Dan Robinette, pers. comm., 2014).

IV. Other sensitivities: none identified

Additional participant comments

Increasing pressure for more water storage projects may result in impacts to the supply and transport of replenishing sediments to beach and dune habitats. Additionally, a growing population and increased inland air temperatures may result in increased pressure on beach and dune habitats. Because of their dynamic nature beach and dune habitats that have sufficient room to migrate will probably be fairly resilient to climate change impacts. However, much of the areal extent of these habitats may be lost.

Adaptive Capacity

I. Extent, integrity, and continuity

Geographic extent of the habitat: 5 (Transcontinental)

- Confidence of workshop participants: High

Structural and functional integrity of habitat: 3 (Altered but not degraded)

- Confidence of workshop participants: Moderate

Continuity of habitat: 3 (Patchy across an area with some connectivity among patches)

- Confidence of workshop participants: Moderate

Supporting literature

Sandy beaches are a small but important component of the North-central California coastline (SIMoN 2014), and occur in varying forms, primarily pocket beaches tucked amongst the rocky coastline and narrow beaches that front cliffs, as well as occasional linear beaches backed by dunes (Hapke et al. 2006). The largest beaches occur near the Gualala and Russian Rivers, and beach/dune systems occur near Bodega Head and Point Reyes (Largier et al. 2010). The structural and functional integrity of dunes is undermined by beach front development, which prevents natural adaptation to changes in shoreline stability (Clark 1996), erosion, and sea level rise (Nordstrom 2000; Schlacher et al. 2007). Other factors, such as altered sediment dynamics and coastal and watershed perturbations, also decrease the integrity of this ecosystem.

II. Resistance and recovery

Habitat resistance to the impacts of stressors/maladaptive human responses: Low-Moderate

- Confidence of workshop participants: Moderate

Ability of habitat to recover from stressor/maladaptive human response impacts: Moderate

- Confidence of workshop participants: Moderate

Additional participant comments

Beach and dune habitats are naturally very dynamic, and with sufficient room to migrate, may prove to be resilient to climate change impacts. However, coastal development and coastal roads/armoring may adversely impact the ability of beach and dune habitats to recover from and adapt to rising sea levels and increased coastal erosion.

III. Habitat diversity

Physical and topographical diversity of the habitat: Low-Moderate

- Confidence of workshop participants: Moderate

Diversity of component species within the habitat: Moderate

- Confidence of workshop participants: Moderate

Diversity of functional groups within the habitat: Low-Moderate

- Confidence of workshop participants: Moderate

Keystone or foundational species within the habitat: Beach and dune habitat quality depends on some key species, such as sand crabs (*Emerita analoga*) that are critical to the food web, and talitrid amphipods (family *Talitridae*) for wrack processing.

Additional participant comments

Other diversity factors important to consider are landscape-level diversity and an intact habitat mosaic, as these are important factors in determining the functionality and value of beach and dune habitats.

Supporting literature

Beaches and dunes are formed from unconsolidated sand from watersheds and coastal bluffs, and are constantly being shaped by wind, waves, and tides. Dune habitats are found in the supralittoral zone, while beach habitats feature three ecological zones: supra-littoral at or above

the drift line, middle intertidal, and lower intertidal (Largier et al. 2010). Landscape level diversity and intact habitat mosaics determine the functional and habitat value of beach and dune systems. (Peter Baye, pers. comm., 2014). Beaches and dunes provide key habitat for a variety of species. For example, dunes are home to many unique and threatened plants, while the uppermost intertidal zones of sandy beaches are important for California grunion (*Leuresthes tenuis*) and smelt spawning (Thompson 1919) and pinniped pup rearing. Open beach and dune habitats also provide feeding and nesting habitat for shorebirds, including the threatened western snowy plover (*Charadrius alexandrines nivosus*), which nests in the dry sand zone. Sand crabs are the most abundant invertebrate in beach and dune habitats, acting as a critical component of the food web by filter-feeding plankton from the ocean and acting as a food source for shorebirds, gulls and sea otters (Largier et al. 2010; SIMoN 2014). Talitrid amphipods play a key role in wrack processing and nutrient cycling (Lastra et al. 2008). Both of these groups are highly sensitive to changes in erosion and storms, among other factors (Largier et al. 2010).

IV. Management potential

Value of habitat to people: High

- Confidence of workshop participants: High
- Description of value: Humans value beach and dune habitats for their natural storm protection, aesthetics, and for the recreational opportunities that they provide, such as surfing, fishing, vacations, and driving of off-road vehicles.

Likelihood of managing or alleviating climate change impacts on habitat: Moderate

- Confidence of workshop participants: High
- Description of potential management options: Management likelihood varies by location. For example, some beaches and dunes will likely be prioritized for beach nourishment, especially those that are of high recreational or ecological value. Protected areas also provide opportunities for beach and dune systems to retreat in the face of sea level rise and erosion. In comparison, beach and dune areas that are backed by development or natural barriers (i.e., cliffs) that prevent migration or prevent natural beach nourishment are likely to disappear. For many of these threatened locations, there is no economic justification for nourishment intervention based on their perceived level of use. Beach nourishment or near-shore disposal sites for dredged materials are available management steps to bolster the adaptive capacity of beach and dune systems.

Supporting literature

Beach clean-ups are a means of both improving quality of habitat and building public support and investment in beach health (Dan Robinette, pers. comm., 2014).

V. Other adaptive capacities:

Critical factors not addressed that may affect habitat's adaptive capacity: sediment supply and transport

- Degree to which these factors affect the habitat's adaptive capacity: High
- Confidence of workshop participants: High

Additional participant comments

Sediment supply and transport are critical to beach and dune habitats, and are impacted by both climate change impacts and human disturbances.

Exposure

I. Future climate exposure[6]

Future climate and climate-driven factors identified (score[7], confidence[8]): sea level rise (5, high), increased storminess (5, high), increased coastal erosion and runoff (5, high), increased flooding (3, low)

Degree of exposure to future climate and climate-driven factors: High

- Confidence of workshop participants: High

Additional participant comments

Potential refugia areas include beaches and dunes that are very wide and/or those that have room to migrate inland (i.e., are not back by development or natural barriers), which may represent only a small percentage of habitat area within the study region. Beach and dune systems are sensitive to extreme increases in the duration or frequency of flooding.

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[6] Supporting literature for future exposure to climate factors is provided in the introduction.

[7] For scoring methodology, see methods section. Factors were scored on a scale of 1-5, with 5 indicating high exposure and 1 indicating low exposure.

[8] Confidence level indicated by workshop participants.

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