Task 1.1: Statewide inventory of coastal dunes

Many site-specific studies of coastal dunes in California exist[55,57-62], yet a comprehensive account of their extents, attributes and changes does not. To address this, we will develop a GIS inventory of key dune attributes (linear and areal extents, morphologies, landscape setting, vegetation, threatened species, critical habitats, ecosystem services) and observed changes (area, land use/cover, shoreline position) using existing publications, historical maps[97] and aerial photography, low altitude imagery from the California Coastal Records Projectd (1972 - 2013), recent, frequent satellite imagery using Google Earth Engine, Planet.org’s API and CoastSat13shoreline change data. A draft inventory will be shared with, and verified by, end-users via regional workshops (Task 3.1) and subsequent field verification campaigns. the updated database will leverage our collective expertise and local knowledge to provide essential, current data to inform ongoing revisions to the CARI database, which is used by federal, state and local agencies in California to coordinate monitoring, status assessments and inform local-scale resilience planning[50].

Regarding site sensitivity and risks, the updated inventory GIS database will provide detailed attributes for the pilot sites including beach/dune form (beach width, dune height, volume, areal extent, accommodation space), function (sediment budgets, aeolian activity, plant cover/communities, vulnerable species, critical habitats, association with wetlands) and ecosystem services (flood control, erosion mitigation, tourism, conservation, etc.).

Task 1.2: Vulnerability assessment

The vulnerability assessment will add value to the updated inventory by identifying the exposure, physical sensitivity and status of resilience to erosion, flooding and SLR for a set of pilot sites (see Table 1, Obj. 2). The extent, duration, responses and approaches to restoration at the sites will also be assessed for promoting resilience (recovery from erosive events, plant community responses, required maintenance/interventions) as a proxy for adaptive capacity.

With the use of CoSMoS, the vulnerability assessment will also be able to assess how the updated inventory of coastal dunes might evolve in space and time in response to SLR, increasing vulnerability to flooding, erosion and habitat loss. Specifically, we will develop a cumulative assessment approach that considers both exposure to coastal hazards and sensitivity of dune ecosystems based on their attributes, responses and services at risk. Hazard exposure variables will include current RSL rates, average and extreme total water levels (TWL), high-tide flood elevations and extent, and shoreline change rates. The sensitivity assessment will build on established, physically-based methods[66-67] that rank and aggregate a net exposure index value. Site sensitivity and risks will be assessed using key attributes of dune form, function and ecosystem services identified from the updated inventory, including plant communities, threatened species, wetlands and other critical habitats, sand supply and beach width, beach-dune sediment budgets, aeolian activity, land use, shoreline change, dune extent and accommodation space. As such, this method considers both site exposure to forcing conditions and resulting susceptibility to change, with its inherent ability to resist change or be resilient. Restoration efforts/responses at sites that have sufficient data will also be assessed to characterize site resilience to erosion and SLR as a proxy for their adaptive capacity. For instance, at the Lanphere Dunes in Humboldt Bay, recent research shows that restored foredunes are more resilient to storm impacts than those with invasive beach grass[16].

Updated projections in the 2022 U.S. Interagency Sea Level Rise Technical Report indicate potential SLR of 0.25-0.30 m by 2050 - an amount roughly equal to that over the last century[68]. RSL rise will vary regionally due to changes in land and ocean heights and will accelerate at rates much faster than those seen in the last 8000 yrs[69]. In response, the state is updating its SLR projections and plans to publish a new Sea-Level Rise Guidancef in June 2023 that will include updated regional SLR scenarios consistent with the 2022 U.S. Interagency Report, updated coastal storm scenarios (1, 20, and 100 yr intervals updated by project partners at USGS) and new high-tide flooding projectionsg [68,70].

These latest projections will be used to evaluate physical exposure and vulnerability of linked beaches and dunes at the pilot sites to habitat loss (intertidal, supratidal, dune), high-tide flooding (frequency and depth), storm-driven total water levels (TWL: waves + runup + surge), observed vs. projected shoreline change and projected SLR. For instance, average or seasonal TWL controls the location of dune vegetation and development[71-73] and can define a threshold for exposure of beach-dune systems to erosion[74-76]. Elevation thresholds can be identified using available LIDAR (e.g., USGS 3DEP LidarExplorer). Observed vs. projected shoreline changes can be examined using CoastSat and CoSMoS, respectively. Annual to multidecadal evolution of sandy beaches to climate variability and SLR scenarios can be reliably predicted and projected using data-assimilated coastal change models[77-79], especially when integrated with satellite-based shoreline observations from CoastSat[27,80]. As part of CoSMoS[24], the USGS has developed coupled projections of beach loss and flooding across California[25-27]. CoSMoSCOAST, the shoreline change component, has been used to understand tipping points of coastal ecosystems[81] and evaluate performance and lifespan of potential beach nourishment projects[82]. Our collaboration with USGS will leverage CoSMoS models and data to characterize the vulnerability and protective benefits of coastal dunes. For example, long-term projections of nearshore wave and TWL conditions, historical shoreline changes and existing model projections of erosion/accretion (at 100-200 m alongshore transects) will help identify sites that are most vulnerable to erosion. CoSMoS-COAST only simulates beach evolution, so our study adds value by providing empirical data from pilot sites and a postdoc to work with USGS to adapt the model to include a dune erosion model, building on prior developments[83-86]. The coupled beach-dune model will be capable of simulating bi-directional sediment transport and feedbacks between sandy beaches and dunes and model their long-term fate with SLR. In turn, this refined model could be applied to assess existing and/or restored dune lifespans.