Hawaiian Islands Coastal Ecosystems: Past, Present, and Future

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Abstract

We provide an overview of the coastal ecosystem of the Hawaiian archipelago and describe the ecological factors that have influenced the ecosystem in the past, present, and future. Coastal ecosystems found throughout the Hawaiian archipelago are subject to oceanic influences such as winds, salt-spray, and wave energy. Two coastal ecosystem sub-types occur in the archipelago and are defined by moisture regime: coastal dry and coastal wet-mesic sub-types. Limited information exists about what coastal ecosystems and their associated ecological communities looked like prior to human-contact. The assumption is that coastal ecosystems were historically more resilient to stochastic events because they had more continuous populations of native flora with a higher faunal diversity. Currently, coastal ecosystems are in decline due to factors such as conversion pressure from expanding development and agriculture and the introduction of invasive species. We analyzed four scenarios for a foreseeable future of coastal ecosystems with varying levels of change in Conservation Management Parameters: conservation values, laws and biosecurity, and development or conservation planning. We anticipate that coastal ecosystems will continue to decline unless significant management change occurs.

Introduction

The Hawaiian archipelago in the Pacific Ocean is more than 3200 km from the nearest continental land mass with extreme variations in elevation, wind, rain, topography, substrate, and hydrology. These variations create unique ecosystems across the archipelago. We provide an overview of the coastal ecosystem in Hawaiʻi and describe the ecological factors that have influenced it over time. Please see the *Physical Geography of the Hawaiian Islands* by Harrington, Pang, and Richardson 2019 for a full description of the unique geography, geology, climate, hydrology and descriptions of the islands in the Hawaiian archipelago.

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Description

Defining Hawaiian Islands Coastal Ecosystems

Coastal ecosystems are defined as near-shore areas impacted by the ocean. Bound by ocean on one side, these ecosystems generally range within 100 m of the high tide, and up to 300 m in elevation. This limit is determined by the effect of seawater on the substratum and plant rooting zone; the limit of spray kill; and the limit of formations such as sand dunes, elevated coral outcrops, and marine terraces, which are created largely through shoreline processes (e.g., inundation or exposure to salt water and onshore flow of ʻehukai salt mist, strong winds, movement of sand by winds, and brackish basal groundwater; see Richmond and Mueller-Dombois, 1972; Gagné and Cuddihy, 1999; Warshauer et al., 2009) and sometimes extends farther inland if strong prevailing onshore winds drive these processes into the lowland zone (TNCH, 2009).

Coastal ecosystems are found on all of the main Hawaiian Islands (Hawaiʻi, Maui, Molokaʻi, Kahoʻolawe, Lānaʻi, Oʻahu, Kauaʻi, and Niʻihau) and offshore islets. The highest species diversity occurs in the least populated and undeveloped coastal areas on the main Hawaiian Islands. These ecosystems also occur on the islands and atolls within the islands in the Northwestern Hawaiian Islands (NWHI or Papahānaumokuākea).

The coastal substrate consists of well-drained talus (the pile of rocks that accumulate at the base of a cliff, chute, or slopes), calcareous (limestone) slopes, and dunes. This ecosystem can be dry (less than 1200 mm annual rainfall), mesic (1200–2500 mm), and wet (more than 2500 mm). The vegetation community within these dry and wet-mesic ecosystems consist of herblands, sedgelands, grasslands, shrublands, mixed communities, and forests (Table 1 and described below).

Pre-human Condition

Information about native vegetation in Hawaiʻi prior to the arrival of humans is limited. Our assumptions are based on existing vegetation, remnants in disturbed areas, patterns of climate and substrates, and a few fossilized remains (Cuddihy and Stone, 1990). Coastal ecosystems were found on all islands in the archipelago in a continuous ring, only interrupted by stretches of recent lava flows or unstable cliff faces (Jacobi and Warshauer, 2017). Native flora and fauna existing today are likely remnants of larger, more extensive past populations of flora and fauna (Gagné and Cuddihy, 1999). What is now an island or atoll within the Northwestern Hawaiian Islands was likely a high elevation island with a varying array of vegetation communities that do not currently exist. For example, typical high island tree species such as loulu (*Pritchardia* sp.) and ʻiliahi (sandalwood, *Santalum elipticum*) on the coral island of Kamole (Laysan) might have been the remnant of a more expansive vegetation community present at one time on a higher elevation island form (Mueller-Dombois and Fosberg, 1998) (Fig. 1).

Vegetation on rocky shores were low growing and mat forming species in areas closest to the ocean (Warshauer et al., 2009), or stunted due to strong winds (e.g., tree species grew to shrub forms) (Gagné and Cuddihy, 1999). Taller plants grew farther inland or where accumulated soil was locally available (Warshauer et al., 2009). A range of conditions at other sites allowed for species diversity within coastal communities (Warshauer et al., 2009). We assume that healthy, functioning coastal ecosystems unaltered by humans had the ability to provide natural protective buffers for inland ecosystems (Fig. 2).

Dry Hawaiian coastal ecosystems historically occurred on all coral atolls and high island remnants of the NWHI, and along the coastlines of all the main islands (Gagné and Cuddihy, 1999). They were likely more extensive on the drier leeward sides of larger

Table 1 Categories and sub-units of Hawaiian coastal systems and dominant plant species and vegetation type were used to classify habitat sub-units based on their elevation and moisture regimes within the coastal boundaries.

Coastal communities		
Coastal dry communities	Coastal dry herblands	*Nama* Herbland
		ʻĀkulikuli (*Sesuvium*) Herbland
	Coastal dry grasslands	ʻAkiʻaki (*Sporobolus*) Grassland
		KĀwelu (*Eragrostis*) Grassland
		Lepturus Grassland
	Coastal dry mixed communities	ʻIlima (*Sida*) Mixed Shrub and Grassland
	Coastal dry shrublands	Naupaka Kahakai (*Scaevola*) Shrubland
		ʻilima (*Sida*) Shrubland
		Maʻo (*Gossypium*) Shrubland
		Hinahina/Kīpūkai (*Heliotropium*) Shrubland
		ʻIliahialoʻe (*Santalum*) Shrubland
		Coastal Cliff Mixed Shrubland
		ʻĀweoweo (*Chenopodium*) Coastal Shrubland
		Naio (*Myoporum*) Shrubland
Coastal wet-mesic communities	Coastal mesic forest	Hala (*Pandanus*) Forest
		Loulu (*Pritchardia*) Coastal Forest

Adapted from Gagné WC and Cuddihy LW (1999) Vegetation. In: Wagner WL, Herbst DR, and Sohmer SH (eds.) *Manual of the Flowering Plants of Hawaiʻi*, pp. 45–114. Honolulu: University of Hawaiʻi Press, Bishop Museum Press.

Fig. 1 Nihoa Island, a high island in the Northwestern Hawaiian Islands.

Fig. 2 Low growing and mat forming shrubs at Ka'ena Point on the island of O'ahu.

islands and on all sides of the smaller, arid islands and atolls in the Hawaiian archipelago (Gagné and Cuddihy, 1999; Landfire, 2016). Certain plants such as naupaka kahakai (*Scaevola taccada*) were able to utilize the brackish groundwater to grow year-round (Gagné and Cuddihy, 1999). Other typical coastal dry vegetation consisted of ʻŌhai (*Sesbania tomentosa*), ʻakiʻa (*Wikstroemia uva-ursi*), naio (*Myoporum sandwicense*), pŌpolo, ʻakoko (*Chamaesyce celasroides*), ʻewa hinahina (*Achyranthes splendens* var. *rotundata*), pāʻū o Hiʻiaka (*Jacquemontia ovalifolia* subsp. *sandwicensis*), and ʻilima (*Sida fallax*) (see Table 2) (Fig. 3).

Wet coastal ecosystems in Hawaiʻi included nutrient-rich flood plains, marshes, lowland riparian, fresh groundwater, and permanent stream areas. These included the coastal wet forests and the coastal mesic forests (see Table 3) (Fig. 4).

Hawaiian vertebrate species such as honu (Hawaiian green sea turtle, *Chelonia mydas*), honu ʻea (hawksbill turtle, *Eretmochelys imbricata*), and ʻīlioholoholoikauaua (Hawaiian monk seal, *Monachus schauinslandi*) frequented coastlines where the offshore waters provide an abundance of limu and reef protection from predatory shark species. ʻŌpeʻapeʻa (Hawaiian hoary bat, *Lasiurus cinereus semotus*) foraged along the coasts searching for insect prey. Nesting seabirds left their young in sandy or rocky burrows to forage in the prey rich sources offshore. Other seabirds used the edge of the vegetation line to lay their eggs away from the high tide.

Table 2 Historic and current condition of coastal dry communities.

	Historic condition	*Current condition*
Coastal dry herblands	Coastal dry herblands occurred in rocky areas, on coralline surfaces, and on mudflats adjacent to lagoons, marshes, and anchialine pools on coraline or basaltic surfaces; from 0 to 5 m elevation; with an annual rainfall from less than 250 mm to more than 1000 mm (Gagné and Cuddihy, 1999). Dominant herb species included hinahina kahakai (*Nama sandwicensis*) and ʻĀkulikuli (*Sesuvium portulacastrum*) (Gagné and Cuddihy, 1999). Other herbaceous plants consisted of pāʻū o Hiʻiaka and ʻohelo kai (*Lycium sandwicense*) (Gagné and Cuddihy, 1999).	Nama and ʻākulikuli dry herbland communities currently occur only where human disturbance is minimized and along coastal bluffs and cliffs where there are rocky areas and coral surfaces (Gagné and Cuddihy, 1999, p. 55). Some of these native communities have been replaced by the non-native slender sea-purslane (*Sesuvium maritimum*).
Coastal dry grasslands	Coastal dry grasslands typically occurred in leeward areas, at sea level to 300 m elevation with an annual rainfall from 250 to 1000 mm, on variety of substrates of well-drained calcareous sand to newly vegetated volcanic flows (Gagné and Cuddihy, 1999). The plant communities were often subject to summer drought and "brown off" (with the exception of ʻakiʻaki (*Sporobolus virginicus*) and kāwelu (*Eragrostis variabilis*) (Gagné and Cuddihy, 1999). ʻAkiʻaki, kāwelu, and *Lepturus repens* were the dominant grasses.	Native coastal dry grasslands are limited to a few coastal dunes on which human disturbance has been minimized (Gagné and Cuddihy, 1999, p. 57). ʻAkiʻaki grasslands have been converted to kiawe forest communities. Nonnative weeds remain the primary threat to ʻakiʻaki, kāwelu, and *Lepturus* grassland communities (Gagné and Cuddihy, 1999, p. 58). ʻAkiʻaki is often the only native understory species beneath kiawe. Otherwise, the understories are dominated by nonnative drought-resistant grasses and herbs, particularly buffelgrass (*Cenchrus ciliaris*) fingergrass (*Chloris* spp.), and guinea grass.
Coastal dry mixed communities	Coastal dry mixed communities occurred on talus slopes or on shallow, rocky, weathered clay soils, especially in leeward areas with an annual rainfall of less than 500 mm, often subject to winter storm salt spray (Gagné and Cuddihy, 1999). ʻIlima was the dominant plant species.	ʻIlima mixed shrub and grassland communities are still found, however, fingergrass now occurs with ʻilima as a dominant hybrid community in this coastal dry habitat. Additionally, in drier sites on the main Hawaiian Islands these communities have usually been replaced by kiawe, koa haole, Christmas berry or klu (*Acacia farnesiana*). Protection by isolation, especially from feral herbivores provides some protection to the native mixed community.
Coastal dry shrublands	Coastal dry shrubland communities occurred mostly on flat, rocky sites in open, widespread coastal areas below 300 m with an annual rainfall of less than 500 mm; small shrubs in this community were subject to harsh environmental conditions (e.g., highly seasonal precipitation, large temperature fluctuations, and intense solar radiation) (Gagné and Cuddihy, 1999). Naupaka kahakai (*Scaevola taccada*), ʻilima, maʻo, hinahina/kīpūkai (*Heliotropium anomalum* var. *argenteum*)/(*H. curassavicum*), and ʻiliahialoʻe (*Santalum ellipticum*) were dominant species. Coastal cliff mixed shrubland, another sub-habitat of the coastal dry shrublands, consisted of a mix of ʻilima, nehe (*Lipochaeta* spp.), ʻakoko (*Euphorbia degeneri*), kāwelu, *Schiedea globosa*, and ʻānaunau (*Lepidium bidentatum* var. *o-waihiense*) species); ʻĀweoweo (*Chenopodium oahuense*) and, pua kala (*Argemone glauca*), naio.	Native coastal dry shrubland communities occur where they are not subjected to grazing. Abandoned grazing lands along coastlines are extensive thickets of koa haole shrublands. Christmas berry and kiawe forest are also components of these shrublands, the latter community prevailing especially where kiawe is able to tap brackish groundwater. Currently predominantly native dry shrublands consist of mostly nonnatives. Naupaka kahakai shrubland occurring on dunes can be mixed with invasive species such as Indian fleabane (*Pluchea indica*), sourbush (*Pluchea carolinensis*) and Christmas berry; on raised coral can be found with stinking passionflower (*Passiflora foetida*); and on basalt cliffs can be found with sweet acacia (*Acacia farnesiana*). ʻIlima, maʻo, and hinahina/kīpūkai, and ʻaʻaliʻi shrublands occur on a few locations in the main Hawaiian Islands. Although severely disturbed by roads, trails, and nonnative weeds and only represented by a single natural occurrence at Makapuʻu on Oʻahu, ʻiliahialoʻe shrubland remains a native-dominated community (Gagné and Cuddihy, 1999). Coastal cliff mixed shrublands grade into nonnative dominated communities from the top to bottom of cliff bases. Native species are not large components of these communities. Most of the native coastal dry shrublands that remain are being destroyed by urbanization, off-road vehicle activity, arson, grazing, and encroachment by nonnative plant species. ʻIlima, ʻāweoweo, and naupaka kahakai shrublands occur on federally protected lands in the NWHI; naupaka kahakai shrublands are fairly dominant in certain coastal areas of the main Hawaiian Islands. Coastal cliff mixed shrublands also have some natural barriers (steepness of cliff slopes) which make it impossible for nonnative ungulates and predators to access, but is almost ubiquitously disturbed by nonnative plants. Although several of these communities occur within the State's Kaʻena Point Natural Area Reserve on Oʻahu, they have not yet received protective management. Maʻo, hinahina/kīpūkai, ʻiliahialoʻe, and naio shrub lands remain unprotected.

Table 2 (Continued)

	Historic condition	*Current condition*
		The coastal dry shrubland is often delineated at the inland boundary by nonnative lowland shrubs and trees (klu, kiawe, koa haole, and Christmas berry) where the degree of salt spray, is minimal. No extant intact naio shrublands currently exist; only remnant scattered clumps of naio occur in the lowlands of O'ahu, such as on the Mokulē'ia side of Ka'ena Point, where they have not been impacted by agriculture or fire and subsequently replaced by nonnative shrublands or forests. On Laysan, this vegetational association was an important element until it was destroyed by introduced rabbits in the early 1900s and replaced by shrublands of Indian fleabane. 'Āweoweo coastal shrublands have since been reintroduced on Lisianski and Laysan.
Coastal dry forests	Coastal dry forests occurred in gently sloping and level lowlands, in areas where there was sufficient soil (Gagné and Cuddihy, 1999). Ground cover consisting of 'aki'aki extended inland beneath taller tree species such as wiliwili (*Erythrina sandwicensis*), 'ohe makai (*Reynoldsia sandwicensis*), and loulu (*Pritchardia* spp.). Typical plants in this community included 'ilima and nehe. Vegetation in the semi-arid conditions on the leeward coasts were able to utilize brackish water found under talus and alluvial substrates.	Additionally, wiliwili, 'ohe makai, and hoary abutilon have been replaced with invasive species such lantana (*Lantana camara*), klu, Christmas berry, koa haole, or kiawe (the latter being the current dominant species in the coastal dry forest). Because kiawe is able to utilize brackish groundwater at great depths it thrives in the semi-arid conditions along this coastal habitat type. Logwood (*Haematoxylum campechianum*) is locally quite abundant and may be codominant with kiawe on the south Kona coast of Hawai'i Island.

Adapted from Gagné WC and Cuddihy LW (1999) Vegetation. In: Wagner WL, Herbst DR, and Sohmer SH (eds.) *Manual of the Flowering Plants of Hawai'i*, pp. 45–114. Honolulu: University of Hawai'i Press, Bishop Museum Press.

Fig. 3 'Ōhai and naupaka on the island of O'ahu.

Other native birds (e.g., finches (Family: Fringillidae), millerbirds (Family: Acrocephalidae), large flightless birds (Family: Anatidae), and various migratory shorebirds) used the native vegetation to build their nests and forage for food sources within the coastal ecosystem. Native insects such as the yellow-faced bee (*Hylaeus* spp.) used the branches of native vegetation to build their nests. In short, these coastal areas were vibrant, diverse ecological communities that could sustain the ecological processes within the ecosystem.

Table 3 Historic and current condition of coastal wet-mesic communities.

	Historic condition	*Current condition*
Coastal wet forests	Coastal wet forests were likely a widespread community which occurred on the windward coastlines (Gagné and Cuddihy, 1999). ʻŌhiʻa (*Metrosideros polymorpha*) and lama (*Diospyros sandwicensis*) were likely widespread on the windward coasts (Gagné and Cuddihy, 1999).	ʻŌhiʻa/lama wet forests no longer exist as a primary dominant community type in the coastal habitat. The wet coastal forests that exist today are mangrove swamps consisting of American mangrove (*Rhizophora mangle*) and oriental mangrove (*Bruguiera gymnorrhiza*).
Coastal mesic forests	Coastal mesic forests occurred on sandy coastlines, wetter lower slopes, valley bottoms, land shelves, and cliff bases from 0 to 493 ft. (150 m) elevation in areas with an annual rainfall of 71–150 in (1800–3800 mm) (Gagné and Cuddihy, 1999). Loulu were the dominant tree species in the coastal wet-mesic habitat.	Both hala and loulu coastal mesic forests are rare. Hala forests are now uncommon but still occur in areas not excessively altered by humans, e.g., example on the Nā Pali coast trail on the island of Kauaʻi. Fairly intact hala forest are also found along the Puna coastline on Hawaiʻi Island but have since been covered by current (2018) lava flows. Only one extant population of loulu coastal forest currently remains on the island of Nihoa. This last lolulu forest community is unique in that it is not subject to invasive mammalian seed predators. Common ironwood (*Casuarina equisetifolia*) which is considered an invasive tree, is another coastal mesic forest community. This community has the capability to grow in monospecific stands due to its aggressiveness in its nitrogen-fixing capability, ability to utilize brackish groundwater, and ability to exclude understory growth with its allelopathic leaves. Coconut (*Cocos nucifera*) trees introduced to Hawaiʻi by early Polynesian settlers are found along coastal beaches, sometimes in dense monotypic stands. Other areas that were once consisting of hala dominated species were farmed and subsequently abandoned by the ancient Hawaiians. These habitats have become dominated by common guava (*Psidium guajava*), strawberry guava (*P. cattleianum*), or black bamboo (*Phyllostachys nigra*), or by Polynesian introductions such as kamani (*Calophyllum inophyllum*), kukui (*Aleurites moluccana*), hau (*Hibiscus tiliaceus*), and tree heliotrope (*Tournefortia argentea*).

Adapted from Gagné WC and Cuddihy LW (1999) Vegetation. In: Wagner WL, Herbst DR, and Sohmer SH (eds.) *Manual of the Flowering Plants of Hawaiʻi*, pp. 45–114. Honolulu: University of Hawaiʻi Press, Bishop Museum Press.

Fig. 4 Loulu coastal forest on the island of Nihoa.

Coastal Ecosystem Viability

We suspect that species viability in coastal ecosystems depended on maintaining multiple, distributed (or redundant) populations of sufficient quality and size to be resilient to change, and with a species richness and representative of a genetic range to survive across their ecological environment over time. The distribution of the coastal ecosystems in the Hawaiian archipelago likely provided the redundancy, which allowed the ecosystem to withstand stochastic events (like volcanic eruptions or hurricanes) on portions of the habitat.

We assume the ecosystem viability of coastal communities before pre-human contact were very resilient, redundant, and well represented and occurred in a continuous ring on all the islands, only restricted by elevation, rainfall, and ocean influences. Because they were widely distributed, it is believed their ability to recover from catastrophic events was more likely. These communities tolerated natural disturbances and any changes or variations to the environment.

Current Condition

Hawaiian coastal ecosystems have been transformed either intentionally (e.g., ornamental or food crops, human residences or hotels, other development such as harbors, jetties, and piers) or inadvertently (e.g., examples plus climate) by humans. Non-native species may become naturalized or outcompete native species. For example, strawberry guava (*Psidium cattleianum*), a Brazilian native tree species, grows from sea level to 4000 ft in elevation (USFS, 2016). Strawberry guava competes with native species, fragments native habitat systems, alters water cycling of Hawaiian watersheds, and promotes secondary invasive species.

Ironwood (*Casuarina equisetifolia*) is an invasive species that is capable of fixing nitrogen and therefore, may alter the soil chemistry (Smith, 1992). It grows rapidly, forms exclusive stands, and its fallen branchlets produce allelopathic chemicals (Smith, 1992). In the NWHI, naupaka, a sand stabilizer of these islands, cannot tolerate the heavy shade from ironwood, thus has suffered from the gradual encroachment and eventual replacement by the invasive species (Smith, 1992). These low lying coastal islands are therefore more susceptible to erosive processes (Smith, 1992).

Koa haole (*Leucaena leucocephala*) is an aggressive pest due to its effective dispersal and potential for rapid population increase (Wester, 1992). Its ability to vigorously resprout and establish by seed after fire exhibits its ability to exploit new sites and shift the ecological systems (Smith and Tunison, 1992).

Coastal dry communities

Coastal dry communities have been inundated or replaced by invasive species such as pickleweed (*Batis maritima*), kiawe (*Prosopis pallida*), koa haole (*Leucaena leucocephala*), Christmas berry (*Schinus terebinthifolius*), sourbush (*Pluchea carolinensis*), guinea grass (*Megathyrsus maximus*) Native species are no longer dominant in the coastal dry forest (Gagné and Cuddihy, 1999); rather, the systems are made up of invasive plants as listed above and in Table 2.

Coastal wet-mesic communities

Coastal wet-mesic communities are represented by forests, generally restricted to the windward side due to the availability of rainfall, and in the NWHI and offshore islets (e.g., loulu valleys on Nihoa, ironwood stands on Midway, loulu on sea cliffs offshore of Moloka'i). Relative to other communities in the coastal system the coastal wet-mesic communities are relatively species-poor, but this may be a result of human alteration (Gagné and Cuddihy, 1999). Coastal mesic and wet forests have been significantly reduced to invasive dominated communities (see Table 3) (Figs. 5–8).

Current Biotic Components of Coastal Ecosystems

The honu, honu 'ea, and 'īlioholoholoikauaua continue to use coastal areas, however, we speculate in less numbers than historic times. 'Ōpe'ape'a continue to forage in and off these habitats. Seabirds (Families: Sulidae, Fregatidae, Diomedeidae, Procellariidae, Hydrobatidae, Laridae, Phaethontidae) are abundant on the NWHI. Honeycreepers and millerbirds continue to breed in coastal shrub communities in the NWHI. Flightless herbivorous birds, such as the moa nalo, are extinct. Native bees (*Hylaeus* spp.) may be found in remnant coastal communities in the main Hawaiian Islands and NWHI. Current threats to native species include introduced plants, mammals (rodents and ungulates), insects that negatively impact the native biota within the main Hawaiian Islands and NHWI in these coastal ecosystems (see below for discussion).

Stressors

Development

Human development modified coastal ecosystems (Warshauer et al., 2009). Structures and sand hardening altered the hydrodynamics and water flow, wave regime, sediment dynamics, grain size, and depositional processes (Fletcher et al., 1997; Miles et al., 2001; Runyan and Griggs, 2003; Martin et al., 2005; Dugan et al., 2011). Beach hardening projects, including placement of seawalls, jetties, sandbags, and hardened structures, reduce coastal ecosystems, leading to the loss of coastal strand. These activities often result in sand compaction, erosion, and additional sedimentation in near-shore ecosystems, resulting in negative indirect effects to the ecological community and the ecosystem. Often, these increase erosion in adjacent areas and the potential for a cascading series of other beach stabilization projects (Fletcher, 2010; Coastal Geology Group, 2016).

When not managed, public access and recreation degrades or eliminates native communities. Vehicular access from tours, individual recreational access, and use of All Terrain Vehicles (ATV's) increases erosion and damages communities by crushing and breaking of native communities.

Ecosystem destruction and modification by urbanization and land use conversion lead to the direct fragmentation of coastal ecosystems and reduce native dominated coastal communities (Warshauer et al., 2009). Fragmentation decreases the total area of

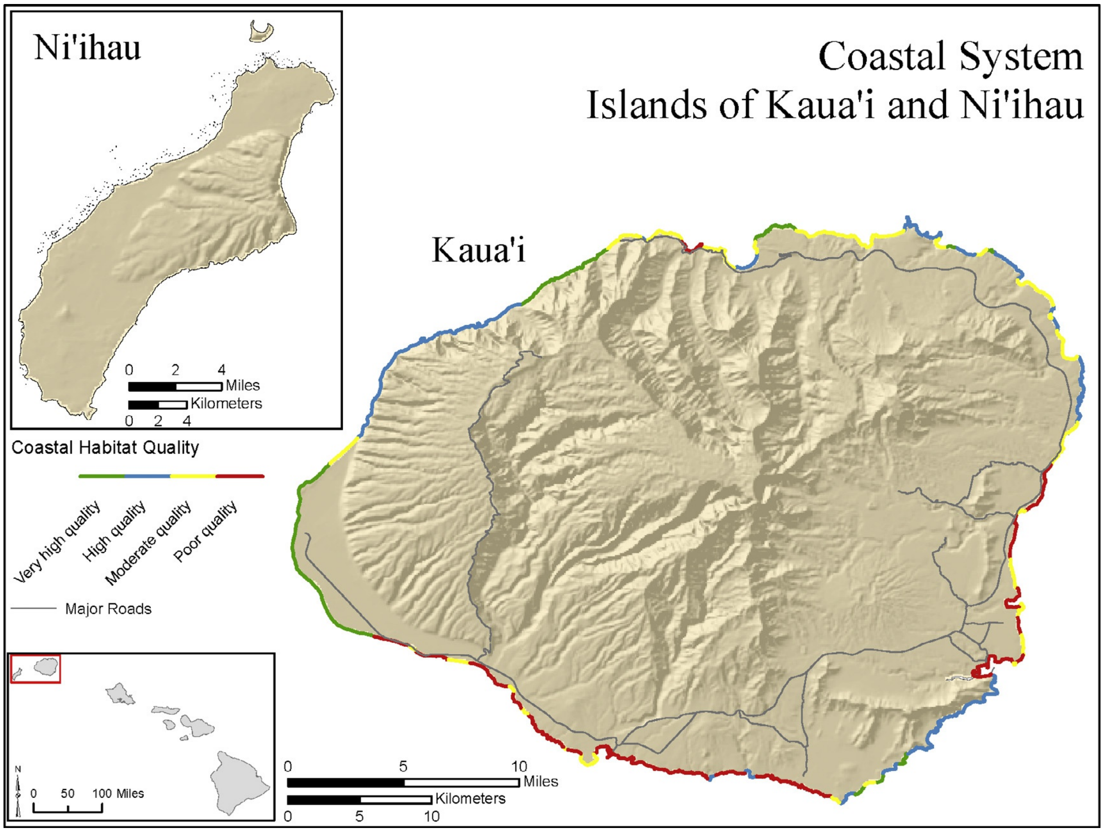

Fig. 5 Coastal ecosystem quality on the islands of Kaua'i and Ni'ihau. From Reeves MK and Amidon F (2018) Habitat status assessment methods—Hawai'i, current condition summaries, August 2018. *Technical Report from United States Fish and Wildlife Service*, 439 pp. Honolulu, HI: Pacific Islands Fish and Wildlife Office.

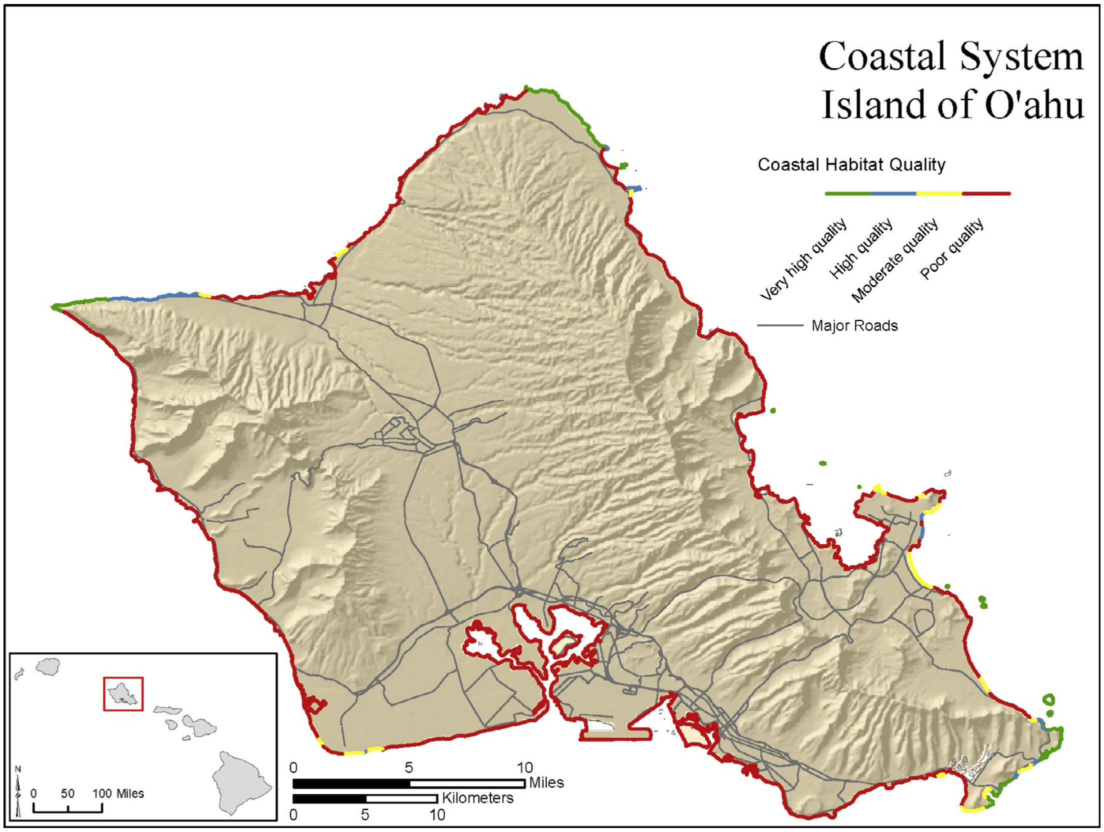

Fig. 6 Coastal ecosystem quality on the island of O'ahu. From Reeves MK and Amidon F (2018) Habitat status assessment methods—Hawai'i, current condition summaries, August 2018. *Technical Report from United States Fish and Wildlife Service*, 439 pp. Honolulu, HI: Pacific Islands Fish and Wildlife Office.

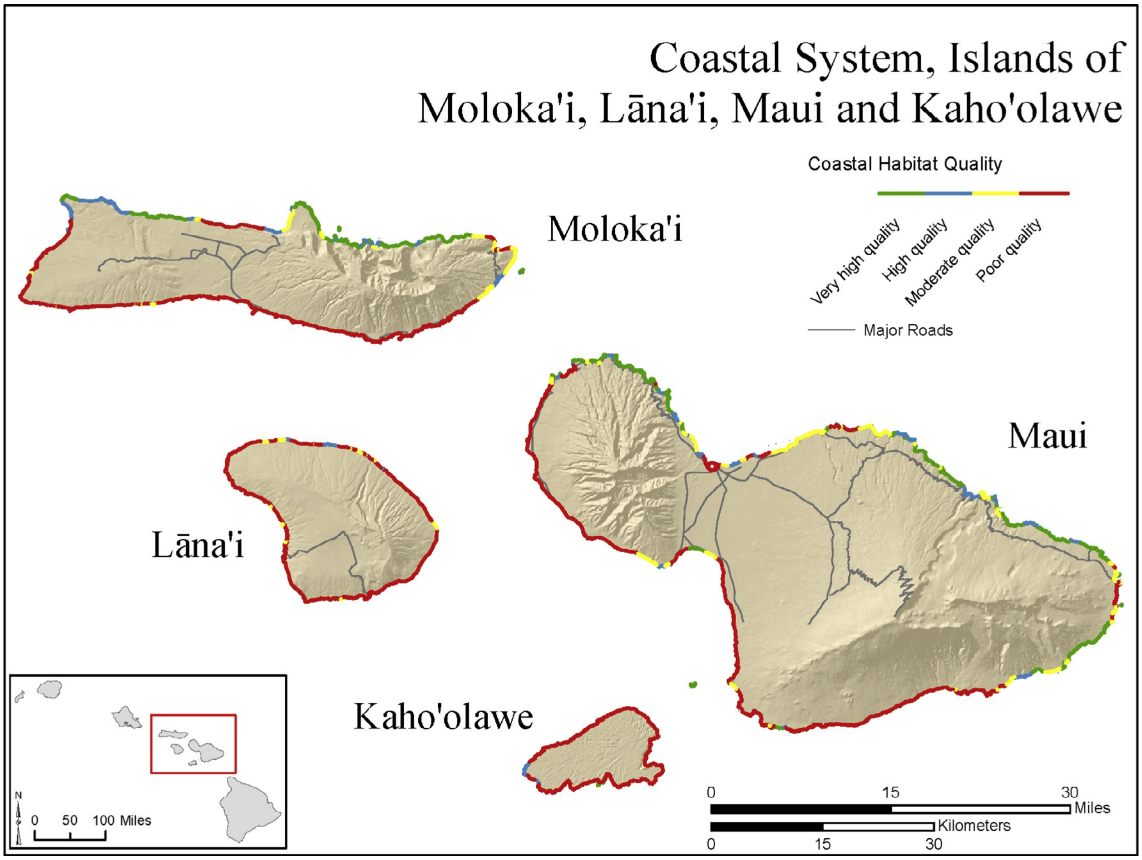

Fig. 7 Coastal ecosystem quality on the islands of Moloka'i, Lāna'i, Maui, and Kaho'olawe. From Reeves MK and Amidon F (2018) Habitat status assessment methods—Hawai'i, current condition summaries, August 2018. *Technical Report from United States Fish and Wildlife Service*, 439 pp. Honolulu, HI: Pacific Islands Fish and Wildlife Office.

the ecosystem and native communities, reduces the diversity and composition of communities found in the ecosystem, and therefore reduces its resiliency (Figs. 9 and 10).

Biosecurity

Four agencies are responsible for inspection of goods arriving in Hawai'i. The Hawai'i Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawai'i, especially insects or plant diseases not yet known to be present in the State. The US Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations. They focus on a wide range of quarantine issues involving non-propagative plant materials (processed and unprocessed); wooden packing materials, timber, and products; internationally regulated commercial species under the Convention in International Trade in Endangered Species (CITES); federally listed noxious seeds and plants; soil; and pests of concern to the greater United States, such as pests of mainland US forests and agriculture. The US Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, conducts pest risk assessments, trains CBP personnel, conducts permitting and preclearance inspections for products originating in foreign countries, and maintains a pest database that, again, has a focus on pests of wide concern across the United States. The USFWS inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq.*), and prosecutes CITES violations.

The State of Hawai'i's unique biosecurity needs are not recognized by Federal import regulations. Under the PPQ's commodity risk assessments for plant pests, regulations are based on species considered threats to the mainland United States and do not address many species that could be pests in Hawai'i. Interstate commerce provides the pathway for invasive species and commodities infested with non-federal quarantine pests to enter Hawai'i. Pests of quarantine concern for Hawai'i may be intercepted at ports in Hawai'i by Federal agents but are not always acted on by them because these pests are not regulated under Federal mandates. Hence, Federal protection against pest species of concern to Hawai'i has historically been inadequate. It is possible for the USDA to grant Hawai'i protective exemptions under the "Special Local Needs Rule," when clear and comprehensive arguments for both agricultural and conservation issues are provided; however, this exemption procedure operates on a case-by-case basis and is

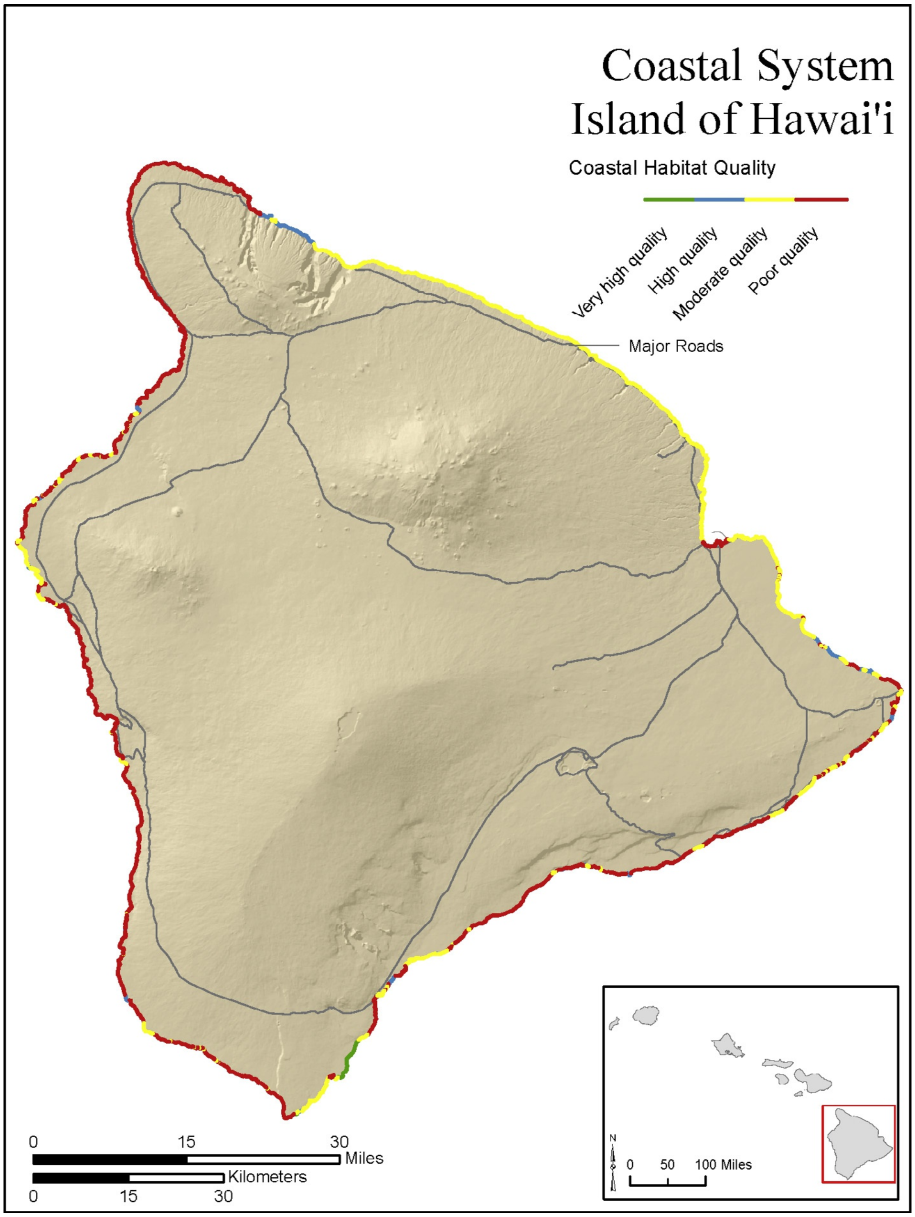

Fig. 8 Coastal ecosystem quality on the island of Hawaiʻi. From Reeves MK and Amidon F (2018) Habitat status assessment methods—Hawaiʻi, current condition summaries, August 2018. *Technical Report from United States Fish and Wildlife Service*, 439 pp. Honolulu, HI: Pacific Islands Fish and Wildlife Office.

Fig. 9 Public parking lot and road at Kaʻena Point Natural Area Reserve entrance.

Fig. 10 ATV and off road trails with nonnative species.

extremely time-consuming to satisfy. Therefore, that avenue may only provide minimal protection against the large diversity of foreign pests that threaten Hawaiʻi.

Adequate staffing, facilities, and equipment for Federal and State pest inspectors and identifiers in Hawaiʻi devoted to invasive species interdiction are critical biosecurity gaps. State laws have recently been passed that allow the HDOA to collect fees for quarantine inspection of freight entering Hawaiʻi (e.g., Act 36 (2011) H.R.S. 150A–5.3). Legislation enacted in 2011 (H.B. 1568) requires commercial harbors and airports in Hawaiʻi to provide biosecurity and to facilitate cargo inspections. As described above, the introduction of new pests to the State of Hawaiʻi is a significant risk to coastal ecosystems.

Invasive animals

Introduced animals have impacted coastal native vegetation and native fauna. Impacts to native species and ecosystems accelerated following the arrival of Captain James Cook in 1778. This expedition and subsequent explorers intentionally introduced European pigs, goats and other livestock for food sources for seagoing explorers (Tomich, 1986; Loope, 1998). The mild climate of the islands and lack of predators led to the successful establishment of large populations of ungulates.

In these systems, ungulates disturb the soil, destroying vegetative cover and native vegetation. They create open areas conducive to further invasion by invasive plants.

Dogs, cats, and mongoose also affect coastal ecosystems: dogs trample plants; mongoose opportunistically eat insect pollinators, fruits, and native plants; and cats spread the parasite, *Toxoplasma gondii*, in feces that affect ʻīliholoakauauaua.

Three species of introduced rats, Polynesian rat (*Rattus exulans*), black rat (*Rattus rattus*), and Norway rat (*Rattus norvegicus*), impact the coastal communities within the ecosystem. Omnivorous rats eat fleshy fruits, seeds, flowers, stems, leaves, and roots (Atkinson and Atkinson, 2000), strip bark and cut small branches (twig cutting) in search of moisture and nutrients, and seriously affect the vigor and regeneration of vegetation (Abe and Umeno, 2011; Nelson, 2012). In the Hawaiian Islands, rats may consume as much at 90% of seeds produced by some native plants, and in some cases prevent regeneration of species completely (Cuddihy and Stone, 1990). Hawaiian plants are particularly susceptible to rat predation because the successful reproduction is affected (Cuddihy and Stone, 1990). Given their impacts on native vegetation, rats have the potential to significantly alter coastal communities.

The introduced house mouse (*Mus musculus*) is most common in lowland ecosystems and abundant over a wide range of vegetation types (Cuddihy and Stone, 1990). Mice have been documented eating insects, grass seeds, fruits (Kami, 1966), and may disrupt plant pollination through destruction of larvae of pollinators (Cole et al., 2000; Cuddihy and Stone, 1990).

Invasive insects

Sometimes when invasive invertebrates feed on or defoliate native plants, the ranges of the native plants are reduced. For example, the erythrina gall wasp (*Quadrastichus erythrinae*) is an invasive invertebrate that impacts wiliwili trees (*Erythrina sandwicensis*). The gall wasp was first discovered on Oʻahu in 2005 and subsequently spread to other main Hawaiian Islands (Heu et al., 2008). Like other gall-forming wasps, they insert eggs into young leaf and stem tissue. Larvae develop and eventually cut exit holes to emerge as adults. Heavily galled plants result in a loss of growth and vigor, while severe infestations lead to defoliation and death (Heu et al., 2008; Yang et al., 2004). As a destructive pest on native wiliwili trees, this wasp impacts coastal communities (by what? Please make this clear).

The black twig borer (*Xylosandrus compactus*), first discovered on O'ahu in 1961, has become widespread throughout the main Hawaiian Islands (Nelson and Davis, 1972). Black twig borers tunnel into woody twigs or branches to lay their eggs. This excavation and the introduction of pathogens damages the host. Severe infestation can kill host plants, including large trees (Tenbrink and Hara, 2007; Nelson and Davis, 1972). Black twig borers have also infested invasive understory shrub species (koa haole and Christmas berry (*Schinus terebinthifolia*)) (Nelson and Davis, 1972).

Naio thrips (*Klambothrips myopori*) was first detected on Hawai'i Island in 2008, attacking the native naio (HDLNR et al., 2013). Thrips feed on the host plant's foliage, resulting in leaf distortion and galls. Heavy infestations lead to leaf curling, dieback, defoliation, and mortality (HDLNR et al., 2013). These trips also impacts native insect herbivores and pollinators that rely on naio for food and/or habitat (HDLNR et al., 2013).

Invasive ants (Family Formicidae) including the big-headed ant (*Pheidole megacephala*), yellow crazy ant (*Anoplolepis gracilipes*), *Solenopsis papuana*, *S. geminata*, longhorn crazy ant (*Paratrechina longicornis*), *Tetramorium bicarinatum*, *T. simillimum*, bicolored trailing ant (*Monomorium floricola*), ghost ant (*Tapinoma melanocephalum*), *Cardiocondyla kagutsuchi*, *C. venustula*, and little red fire ants (*Solenopsis geminate*) compete with and displace native invertebrates for nectar food and nesting resources (Howarth, 1985; Hopper et al., 1996; Holway et al., 2002; Daly and Magnacca, 2003; Lach, 2008).

Gray bird grasshopper (*Schistocerca nitens*) has the potential to completely defoliate the native vegetation and has been documented on the island of Nihoa (Latchininsky, 2006, 2008; Plentovich et al., 2015). *S. nitens* feeds on broad-leafed plants and avoid grasses (Latchininsky, 2006; Plentovich et al., 2015). *S. nitens* outbreaks in 2002 and 2004 on the island of Nihoa posed a major threat to the vegetation (Gilmartin, 2005), especially to endangered plants (Plentovich et al., 2015).

Invasive plants

The historic flora consisted of approximately 1000 taxa, 89% of which were endemic. Over 800 plant taxa have been introduced, and nearly 100 of these are considered pests (Smith, 1985; Cuddihy and Stone, 1990; Gagné and Cuddihy, 1999). Some plants were brought for food or cultural reasons and are well established along coastlines (Cuddihy and Stone, 1990). Plantation owners and the territorial government of Hawai'i introduced nonnative trees for reforestation to protect water resources. Ranchers intentionally introduced pasture grasses and other nonnative plants for agriculture, and sometimes inadvertently introduced weeds. Other plants were brought for horticultural value (Scott et al., 1986; Cuddihy and Stone, 1990). Invasive plants compete for resources; modifying the availability of light; altering soil-water regimes; modifying nutrient cycling processes; altering fire characteristics of native ecosystems; lead to incursions of fire-tolerant nonnative plant species; and indirectly inhibit the growth requirement of native species (e.g., ironwood). Nonnative tree species constitute the greatest threat within coastal strand communities, especially if they can disperse readily and form dense thickets above native vegetation (Warshauer et al., 2009).

Fire

Although the number and size of wildfires have increased on the main Hawaiian Islands; their occurrences are unpredictable (Gima, 1998; County of Maui, 2009; Hamilton, 2009; Honolulu Advertiser, 2010; Pacific Disaster Center, 2011). Fires may create open ecosystems for invasive plants to exploit (D'Antonio and Vitousek, 1992). For example, Fountain grass (*Pennisetum setaceum*) is a fire-adapted nonnative plant that produces a high fuel load that increases fire intensity; the species regenerates quickly after fire and establishes rapidly in burned areas (Fujioka and Fujii 1980 *in* Cuddihy and Stone, 1990; D'Antonio and Vitousek, 1992; Tunison et al., 2002).

Storms

Hurricanes exacerbate the impacts of other threats. By destroying native vegetation, hurricanes open tree canopy, modify the availability of light, and create disturbed areas conducive to invasion by invasive plants (Asner and Goldstein, 1997; Harrington et al., 1997). Major tsunamis occur worldwide about once every 10 years, on average, and almost 60% of those occur in the Pacific Ocean (Pacific Tsunami Warning Center, 2009). In 2011, a tsunami caused by an earthquake in Japan swept over Kuaihelani's Eastern Island and HŌlanikū's Green Island, where it inundated plants, spread plastic debris, as it traveled inland and had devastating effects to the native biota (Leary, 2011).

Flooding and erosion

In the open sea near Hawai'i, rainfall averages 630–760 mm per year, and some places may receive up to 15 times this amount, depending on topography (Wagner et al., 1999). Rain may fall at rates of 76 mm per hour and reach 1000 mm in 24 h, and the flash floods bring sediments down streams and narrow gulches; which may damage, destroy, or eliminate one or more isolated occurrences of native plants that persist in low numbers and limited geographic range due to invasive plants (Wagner et al., 1999). This compromises the redundancy and resilience of the ecosystem.

Sea level rise

According to the Intergovernmental Panel on Climate Change, the oceans are now absorbing more than 90% of the heat added to the Earth's climate ecosystem (Bindoff et al., 2013 and Rhein et al., 2013 as cited in Bindoff et al., 2019). Since 1961, this absorption has caused average global ocean temperatures to increase, seawater to expand, and sea-levels to rise. Melting ice-sheets, ice caps, and alpine glaciers also influence ocean levels. Analysis of the historical record indicates ocean surface temperature in Hawai'i has been increasing over the past century, and accelerated since the 1970s (Fletcher, 2010). Although coastal ecosystems will likely move inland as sea-level rises, low elevation islands are predicted to completely become affected by increased erosion and exposed to marine inundation (Fletcher, 2010).

Interactive conservation actions

Impacts from stressors are addressed through active management (e.g., predator and invasive species control, fencing, outplanting, etc.), land protections, laws and regulations, and education and outreach. These approaches are implemented by state and federal government agencies, private organizations, and non-government organizations (NGOs) (Table 4). Given that land ownership of this ecosystem is spread among these parties, partnerships are also formed to manage the ecosystem collectively. Many of the organizations and agencies that contribute to the protection and management of coastal areas are described in Table 4. The laws and regulations governing the work in Hawai'i may be found in Table 5.

Summary of Interactions

The two most significant stressors of coastal ecosystems are the conversion/fragmentation of land due to development pressure, and the ongoing impact of invasive species. The laws, regulations, land protection, and management actions are not currently enough to prevent the overall decline of native coastal ecosystems. The rate of native coastal ecosystem decline is associated with development pressure (e.g., O'ahu, Maui, Kaua'i, and Hawai'i). In these areas the fragmentation reduces resiliency, and the systems are unable to withstand normal stochastic events. Throughout coastal ecosystems, invasive animals and plants outcompete native species, resulting in invasive-dominated coastal communities.

Future Scenarios

Three conservation management parameters (CMPs) will drive the condition of coastal ecosystems into the future. These conservation parameters capture the social and legal mechanisms under which natural resource conservation is carried out. The CMPs are as follows:

(1) *Conservation Values*: stakeholder involvement and public opinion determine the formulation, implementation and funding of natural resource conservation.
(2) *Laws and Biosecurity*: national, state, county, and city regulations are the means by which natural resource conservation and biosecurity are implemented. (e.g., hunting regulations, Clean Water Act, Endangered Species Act, local laws, etc.).
(3) *Development or Conservation Planning*: planning for development, protection, or both will result in losses or gains in natural resource conservation or biosecurity and implementation of these plans are key.

The year 2035 is the extent of the "foreseeable future," and is based on the projected divergence of IPCC Representative Concentration Pathway (RCP) climate change scenarios (van Vuuren et al., 2011a,b). The foreseeable future scenarios considered in this ecosystem assessment are explained below.

Future Scenario One

Scenario One is the status quo, and considered to be the most likely future scenario, and serves as a "baseline" for comparing the future scenarios. There is no change in the implementation of the three CMPs between 2018 and 2035. The current rate of change in land cover will continue through the foreseeable future. Human populations and residential, commercial, and agricultural land development will likely continue to expand, causing ecosystem stressors to continue to increase. It is also probable that Coastal Dry: Herblands, Grasslands, Shrublands, Mixed Communities; and Coastal Wet-Mesic Forests will continue to decline in extent, quality, and function. Native vegetation will continue to give way to an invasive dominated landscape. Resorts and residential communities along coastlines will expand. As development pressure continues, the remaining coastlines will become more fragmented and will be less resilient to stochastic events.

The conditions of each coastal sub-type will continue to slowly decline in Scenario One. Coastal areas will continue to decline in extent and function due to impacts from feral ungulates. High priority invasive weed species, such as koa haole and Christmas berry will expand along coastlines and form monotypic stands. Under a continuation of current bio-security laws, it is likely that new pathogens, diseases, and invasive plant and animal species will be introduced to coastal ecosystems. Erosion will increase, particularly along coastal bluffs, cliffs, and areas prone to strong wave energy. Drought and fire will marginalize the coastal strand. Sea level will rise approximately 1.5 mm per year or more (Coastal Geology Group, 2008) and low lying islands in the NWHI (Laysan, Lisianski, Pearl and Hermes, Midway, French Frigate Shoals, and Kure) will be vulnerable to wave-driven flooding or submersion.

Table 4 Conservation efforts of multiple organizations and agencies.

Protected area	*Location information*	*Landowner/ manager*	*Protected acreage (ac)*	*Conservation importance*
Hono O Nā Pali NAR:	Kaua‘i	Hawai‘i Department of Land and Natural Resources (DLNR)	These cliffs are dominated by common coastal plants such as kāwelu (*Eragrostis variabilis*), ‘āhinahina (*Artemisia australis*), ‘akoko, nehe, ko‘oko‘olau, ‘ilima (*Sida fallax*), and akoko (*Chamaesyce celastroides*)	Lowland coastal systems containing steep cliffs characterized by plants found in drier areas
Ka‘ena Point NAR	O‘ahu	DLNR	A nesting area for the Laysan albatross and rest area for ‘īlioholoholoikauaua	Protection of coastal dry shrublands and rare coastal plants.
Oloku‘i NAR	Moloka‘i	DLNR	The reserve encompasses the mountain plateau to sea cliffs and is one of the very few areas undisturbed by feral ungulates	Protection of coastal dry grasslands
‘Ahihi-Kina‘u NAR	Maui	DLNR	The area contains examples of pioneer vegetation that serve as systems for rare plants, insects, and birds	Protection of coastal dry shrublands, coastal mesic communities
Manuka NAR	Hawai‘i Island	DLNR	Unit extends from 600 ft. (183 m) in elevation down to the coastal boundary Low goat damage found in the coastal regions (State of Hawai‘i 2018).	Protection of coastal dry shrubland (‘ilima dominated) and lowland dry grasslands (pili)
Pu‘u O Umi NAR	Hawai‘i Island	DLNR		This reserve contains dry coastal sea cliffs, coastal dry shrublands and grasslands.
Haleakalā National Park, Kīpahulu District	Maui	National Park Service (NPS)	Located on the east side of Maui, the Kīpahulu District protects an intact ahupua‘a (traditional native Hawaiian land division)	Protection of native coastal strand of hala and naupaka communities
Kalaupapa National Historical Park	Moloka‘i	NPS	The park’s boundary extends for a quarter mile offshore and includes 2000 acres of ocean, two small offshore islands, and wet shorelines. The offshore islands of ‘Ōkala and Huelo support coastal mesic system for loulu and the endemic pua‘ala (*Brighamia rockii*). On the ground management such as invasive plant control, fencing, and ungulate removal are conducted.	
The Ala Kahakai National Historic Trail, Kaloko-HonokŌhau National Historical Park, Pu‘ukoholā Heiau National Historic Site, Pu‘uhonua o HŌnaunau National Historical Park,	Hawai‘i	National Park Service (NPS)		Although the main purpose of these parks are cultural and public use, the coastal system management conservation actions exist to maintain the processes and native strand system that allow these areas to persist.
‘Āpua Point, Keauhou, Halapē, and Ka‘aha	Hawai‘i	NPS	Coastal areas within the NPS’s Hawai‘i Volcanoes National Park that span approximately 20 miles across the coastline.	Contains dry coastal herblands, grasslands, and shrublands. Actions to conserve the coastal system in the park include endangered species monitoring and recovery, system restoration, nonnative plant and animal management, and fire ecology.
Kīholo bay	Hawai‘i	The Nature Conservancy (TNC) of Hawai‘i	7 ac (3 ha)	Contains a vital interface between land and coastal waters, providing system for native flora and fauna.

Table 4 (Continued)

Protected area	*Location information*	*Landowner/ manager*	*Protected acreage (ac)*	*Conservation importance*
Moʻomomi Preserve	Molokaʻi	TNC managed in partnership with DLNR through the Natural Area Partnership Program.	Preserve is 921 acres (373 ha)	Sand dunes and beach system. Portions of the preserve dunes are lithified (sand dunes that become solidified) and are distinct in geological appearance and native strand.
Kamehame beach	Hawaiʻi	TNC	20 ac (8 ha)	Protection of nesting habitat for honu ʻea. System consists of naupaka with other coastal plants like ʻākiʻa, naio, and pāʻū o Hiʻiaka.
Akoakoa	Hawaiʻi	Kamehameha Schools	Three acre (1 ha)	Coastal bluff located along the Kohala; managed for ungulates and invasive plants; restoration of common native plants.
Koholālele	Hawaiʻi	Kamehameha Schools		Coastal bluff along Hāmākua coast; restoration of native, food, and canoe plants.
Kahanu Preserve	Maui	National Tropical Botanical Garden (NTBG)	122 ac (49 ha) unit	Contains the last remaining coastal wet forests in Hawaiʻi (dominated by hala trees); preserve is located in a key part of the larger coastal wet forest adjacent to Kahanu Garden and Piʻilanihale Heiau.
Lāwai Kai	Kauaʻi	NTBG	80 ac (32 ha)	The garden is situated next to Lāwaʻi bay, important habitat for honu.
Coastal systems protected by conservation easements at Keopuka, South Kona, and Kaiholena, Kohala.	Hawaiʻi	Hawaiian Islands Land Trust (HILT)	More than 277.5 ac (112 ha)	These lands are conserved for shoreline and open space.
Conservation easement at Makaʻalae, Hana; Hawea, Kapalua; and Papaʻula, Wailiku; Kīpahulu; Kaulahao; and Hana Kakio II as well as fee ownership at the Waiheʻe	Maui	HILT	More than 467.63 ac (189 ha)	For the protection of coastal dunes
Purchase of Honolua/Lipoa	Maui	HILT	Over 244 ac (99 ha)	To preserve coastal system.
Coastal system protected by conservation easement at Pohaku Pili	Molokaʻi	HILT	over 76 ac (31 ha)	To preserve coastal system.
Wainiha and Kahili Beach Preserves are owned by HILT	Kauaʻi	HILT	Over 18 ac (7 ha)	Protection of coastal system
Conservation easement at Waikalua	Kauaʻi	HILT	Over 18 ac (7 ha)	Protection of coastal system
Coastal system protected by the assistance of HILT at Kahili Beach and Hanalei/Black Pot Beach Park Expansion.	Kauaʻi	HILT	Approximately 3.7 ac (1.5 ha)	Protection of coastal system
Assisted with the purchase and conservation of AwĀwamalu (Ka ʻIwi Coast) and the North Shore.	Oʻahu	HILT	Over 812 ac (329 ha)	Protection of coastal system

Future Scenario Two

A slight increase in the CMPs marginally improves conservation management. Conservation Agencies and stakeholders work with increased but limited resources to slow or stop the degradation of landscape areas. Although the human population increases, development does not substantially increase. A slightly improved biosecurity effort reduces invasive species but some plant diseases but increases are still expected. The small increased support of natural resource management does not alter wildfire frequency or intensity much beyond Scenario One.

The CMP-supported conservation does not prevent, mitigate, or reverse the impacts of climate change-related stressors. Coastal Dry Herblands, Grasslands, and Shrublands, Mixed Communities, and Coastal Wet-Mesic Forests will continue to show a decline in extent, quality, and function. An increase in invasive plants and feral ungulates dominate the landscape. As development continues

Table 5 Hawaiʻi laws and regulations related to conservation.

Title	*Year implemented*	*Authority*	*Intent/purpose*
Endangered Species Act	1973	Federal (USFWS and NMFS)	Protects critically imperiled species from extinction
50 CFR 16	1974	Federal	Implements the Lacey Act (18 USC 42), which prohibits importation of injurious species
Convention on International Trade in Endangered Species	1975	International	Ensures that international trade in specimens of wild animals and plants does not threaten the survival of the species in the wild
Executive Order 11987	1977	Federal	Charges Executive agencies with restricting the introduction of exotic species into the natural ecosystems on federal lands; and encourages States to do the same
Hawaiʻi Administrative Rules, Title 4, Subtitle 6, Chapters 68 and 70	1981	Hawaiʻi (Department of Agriculture)	Rules/amendments for noxious weeds, plant and non-domestic animal quarantine, plant import, and bromeliad import
Executive Order 13112	1999	Federal	Requires that a Council of Departments dealing with invasive species be created to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause
HRS 194-2	2002	Hawaiʻi (Department of Land and Natural Resources)	Establishes Hawaiʻi Invasive Species Council (HISC)
Act 85	2003	Hawaiʻi (HISC)	Conveys statutory authority to HISC to continue to coordinate approaches among the various State and Federal initiatives for the prevention and control of invasive species
HRS Chapter 205A for Coastal Zone Management	2006	Hawaiʻi (DLNR)	To preserve, protect, and where possible, to restore the natural resources of the coastal zone of Hawaiʻi
Act 36 (2011) HRS 150A-5.3	2011	Hawaiʻi (DOA)	Imposes a fee for the inspection, quarantine, and eradication of invasive species contained in any freight brought into the State
HB 1568	2011	Hawaiʻi (DOA)	Requires commercial harbors and airports in Hawaiʻi to provide biosecurity and to facilitate cargo inspections
HRS 174C Hawaiʻi State Water Code	2013	Hawaiʻi (CWRM)	Establishes Commission on Water Resource Management and Water Resource Management Fund
Executive Order 13751	2016	Federal	To prevent the introduction of invasive species and provide for their control, and to minimize the economic, plant, animal, ecological, and human health impacts that invasive species cause (amends EO 13112)
7 CFR 360.200	2018	Federal	Designates certain plants as noxious weeds

with the construction of resorts and residential communities, coastal ecosystems decrease in area. However, slight growth in natural resource conservation and biosecurity results in conservation easements. Agencies slightly increase management efforts by strategically fencing areas which protect bio-diversity in native coastal systems. Sea level rise impacts coastal zones as in Scenario One.

Future Scenario Three

There is a small to moderate decrease in conservation actions in the CMPs that relaxes biosecurity controls, resulting in reduced conservation efforts. An expanding human population requires increased land use for agriculture and development. Economic development outpaces conservation. Nonnative plants and recreation areas will expand. Feral ungulate populations will grow. Wildfire will increase. Coastal Dry Herblands, Grasslands, and Shrublands, Mixed Communities; and Coastal Wet-Mesic Forests will be severely reduced in extend, quality, and function. With extensive localized management, some native plant species may persist in park-like settings or in areas where land development is not possible. The value of current conservation easements and protected areas will diminish and sales of protected lands by private companies and NGO's could expand and facilitate development. As fragmentation increases in these coastal ecosystems, an invasive-dominated ecosystem will occur.

Future Scenario Four

There is a moderate to large increase in conservation actions in the CMPs that substantially improves conservation through a robust effort to engage stakeholders to identify and prioritize landscapes needed for conservation and restoration. The needs of an expanding human population are addressed through more efficient land use governance based on redevelopment rather than development of undeveloped areas. Modern and novel agricultural practices focus on those that do not affect existing natural areas or areas needed for native ecosystem restoration. Substantially improved biosecurity regulations decrease introductions of invasive species and plant diseases. These improved land management actions result in the decreased extent and frequency of wildfire. Climate change-related stressors continue but resiliency increases.

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