USDA Natural Resources Conservation Service

Ecological site VX163X01X005 Aquic Coastal Wetland

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General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

MLRA notes

Major Land Resource Area (MLRA): 163X–Alluvial Fans and Coastal Plains

This MLRA is in the State of Hawaii on the islands of Maui, Lanai, Molokai, Oahu, and Kauai. Elevation ranges from sea level to 800 feet (0 to 244 meters) with elevation extremes up to 1,600 feet (488 meters). The terrain is nearly level and gently sloping coastal plains and adjacent alluvial fans. Beneath the unconsolidated sediments are basalt, coral limestone, calcareous sand deposits, volcanic ash, coral sand, and fill. Average annual precipitation ranges from 10 to 40 inches (254 to 1,016 millimeters) with precipitation extremes up to 122 inches (3,099 millimeters) in select places on Oahu and Kauai (Giambelluca et al., 2013). Most of the rainfall occurs from November through March during kona storms that come in from the leeward side of the islands. Average annual temperatures range from 68 to 82 degrees F (20 to 28 degrees C) with little seasonal variation (Giambelluca et al., 2014). Dominant soils are Mollisols, Aridisols, Entisols, and Vertisols with an isohyperthermic soil temperature regime and aquic or aridic (torric) to ustic soil moisture regimes. Vegetation consists of forbs, grasses, and shrubs with some trees. Almost all the plant species typically encountered are introduced species that have become naturalized in Hawaii (USDA-NRCS, 2006).

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 163 - Alluvial Fans and Coastal Plains.

The Aha Moku System, which dates back to the 9th century and has been passed down through oral tradition and generational wisdom, effectively sustains Hawaii's natural ecosystems and environment (DLNR, 2024). This site-specific and resource-based approach balances land and ocean resources essential for fostering healthy, thriving communities. Grounded in Native Hawaiian generational knowledge, the Aha Moku System emphasizes community consultation to prioritize the health and welfare of Hawaii’s natural and cultural resources. It is rooted in the concept of 'ahupua'a, the traditional system of land and ocean management in Hawaii. For collaboration, this ecological framework encompasses the following mokus:

Kauai Moku Acres: Kona (2,110), Puna (590), Halele'a (477), and Ko'olau (97).

Oahu Moku Acres: Ko'olauloa (1,331), 'Ewa (928), Ko'olaupoko (569), Kona (488), Waialua (288), and O'ahu (73).

Ecological site concept

This ecological site occurs on coastal plains in scattered locations around the coastlines of Kauai and Oahu, where it is accessible from state highways. Many of the former wetlands have been drained and are used for homesites, urban development, pasture, or crops (USDI-USGS, 2006). This is particularly the case for Kaloko clay and Nohili clay on Kauai.

The central concept of the Aquic Coastal Wetland is of low elevation sites near the ocean that have poorly, and very poorly drained soils formed in alluvium deposited over calcareous material or, in some cases, muck. Soils are wet due to subsurface water that rises near or to the soil surface; some sites may be ponded or flooded occasionally. Water is fresh where streams or fresh groundwater approach the ocean and brackish where freshwater mixes with salt water. Vegetation is a mix of woody species, forbs, and especially sedges, rushes, and grasses (USDA-SCS, 1972). Many species inhabit a spectrum of salinity along the gradient.

Associated sites

VX158X01X401	**Isohyperthermic Ustic Naturalized Grassland Koa haole/guineagrass/glycine (Leucaena leucocephala/Urochloa maxima/Neonotonia wightii)** The Isohyperthermic Ustic Naturalized Grassland Ecological Site has a similarly warm but slightly moister climate compared with this ecological site, but it has well drained soils that support rangeland vegetation or dry forest rather than wetlands.
VX163X01X002	**Sandy Shrubland** The Sandy Shrubland Ecological Site has a similar cliimate to this ecological site, but it has sandy, excessively drained soils that support dry rangeland vegetation rather than wetlands.
VX163X01X004	**South and West Aspect Isohyperthermic Naturalized Grassland** The South and West Aspect Isohyperthermic Naturalized Grassland Ecological Site has a similar climate to this ecological site, but it has well drained soils that support dry rangeland vegetation rather than wetlands.

Table 1. Dominant plant species

Tree	(1) *Hibiscus tiliaceus*
Shrub	Not specified
Herbaceous	(1) *Bacopa monnieri* (2) *Schoenoplectus tabernaemontani*

Legacy ID

R163XY005HI

Physiographic features

This ecological site occurs on tidal flats on coastal plains (USDA-SCS, 1972).

Table 2. Representative physiographic features

Landforms	(1) Coastal plain > Tidal flat
Runoff class	Very low to low
Flooding frequency	Rare to occasional
Ponding frequency	Rare to occasional
Elevation	0–12 m
Slope	0–2%
Water table depth	46–183 cm
Aspect	W, N, NE, E, S

Table 3. Representative physiographic features (actual ranges)

Runoff class	Not specified
Flooding frequency	Not specified
Ponding frequency	Rare to frequent
Elevation	0–30 m
Slope	Not specified
Water table depth	Not specified

Climatic features

Summary for this ecological site

Rainfall statistics were determined from University of Hawaii's Rainfall Atlas Raster Data

(Giambelluca et al., 2013). Most of the precipitation falls from October through April. Representative (20th and 80th percentiles) values for annual average precipitation range from 20 to 46 inches (508 to 1,168 millimeters) while actual (10th and 90th percentiles) values for annual average precipitation range from 19 to 65 inches (483 to 1,651 millimeters). Extreme values range from 18 to 91 inches (457 to 2,311 millimeters). The mean annual precipitation is 36 inches (914 millimeters) and the median annual average precipitation is 31 inches (787 millimeters).

Temperature statistics were determined from University of Hawaii's Surface Temperature Raster Data (Giambelluca et al., 2014). Representative (20th and 80th percentiles) values for annual temperatures range from 75 to 77 degrees F (24 to 25 degrees C) while actual (10th and 90th percentiles) values for annual temperatures range from 75 to 81 degrees F (24 to 27 degrees C). Extreme values range from 73 to 82 degrees F (23 to 28 degrees C). The mean annual temperature is 77 degrees F (25 degrees C) and the median annual temperature is 75 degrees F (24 degrees C).

The data presented in the climate normals tables below are from the Western Region Climate Center (Western Regional Climate Center, 2020). The available climate station data are most representative of the low and moderate precipitation areas of this ecological site. I used these data because they provide a reasonable approximation of the University of Hawaii data presented above.

General principles

Air temperature in the Hawaiian Islands is buffered by the surrounding ocean so that the range in temperature through the year is narrow. This creates "iso" - soil temperature regimes in which mean summer and winter temperatures differ by less than 6 degrees C (11 degrees F).

The islands lie within the trade wind zone. Significant amounts of moisture are picked up from the ocean by trade winds up to an altitude of more than about 6,000 feet (1,850 meters). As the trade winds from the northeast are forced up the mountains of the islands their moisture condenses, creating rain on the windward slopes; the leeward sides of the island receive little of this moisture (USDA-SCS, 1972; Western Regional Climate Center, 2020).

Hawaiian indigenous understanding recognized two seasons: Kau or Kauwela (dry season), and Ho`oilo (wet season). During Kau, the sun is directly overhead, days are long and warm, and the trade winds are stronger and more consistent; Kau started on the first new moon in May when the Pleiades set at sunrise (Handy et al,. 1991). During Ho’oilo (wet season) the sun is declined toward the south, days are shorter, temperatures cooler and winds more variable and generally started with the first new moon in November. Ho’oilo is also the season when extensive low-pressure systems often approach the islands from the west, producing heavy rainstorms that primarily affect the leeward sides, but can envelope the entire island. (Malo, 1903; Handy et al., 1991; Sanderson, 1993).

These major storms occur most frequently between October and March. Differences in rainfall amounts between winter and summer are most marked in low elevation dry areas; wetter areas exhibit less seasonal variation in rainfall (USDA-SCS, 1972; Western Regional Climate Center, 2020).

On the windward sides of the islands, cool, moist air at higher elevations descends toward the ocean where it meets the trade winds; this process brings rainfall, often at night, to lower elevation areas (USDA-SCS, 1972; Western Regional Climate Center, 2020).

Table 4. Representative climatic features

Frost-free period (characteristic range)	365 days
Freeze-free period (characteristic range)	365 days
Precipitation total (characteristic range)	508-1,168 mm
Frost-free period (actual range)	365 days
Freeze-free period (actual range)	365 days
Precipitation total (actual range)	483-1,651 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	914 mm

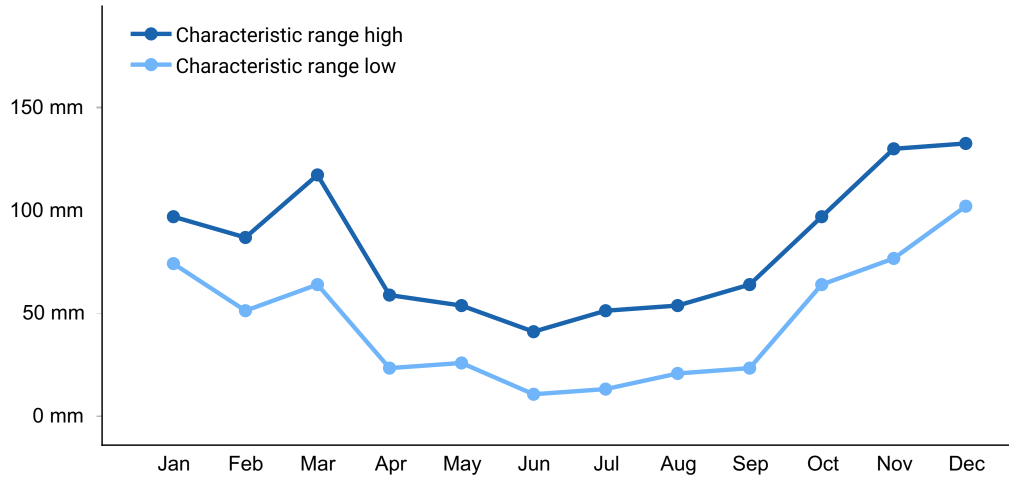

Figure 1. Monthly precipitation range

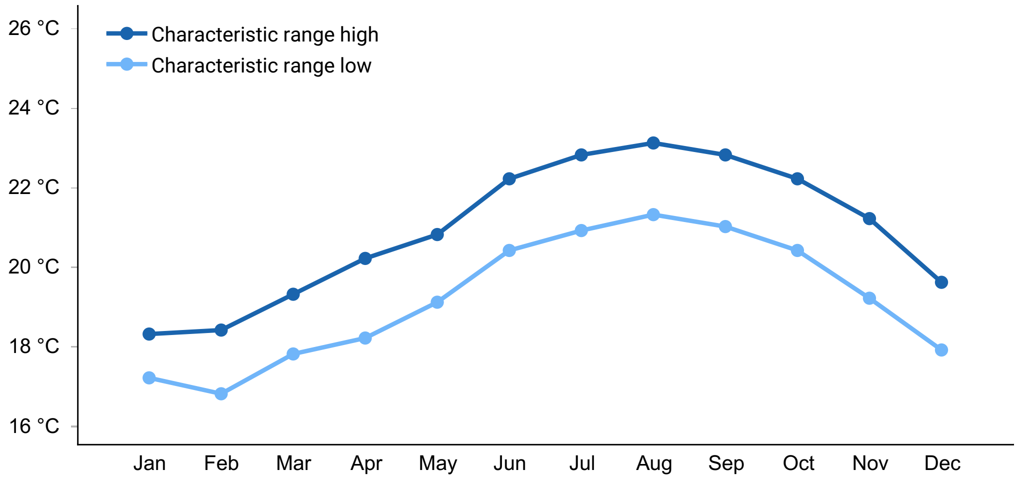

Figure 2. Monthly minimum temperature range

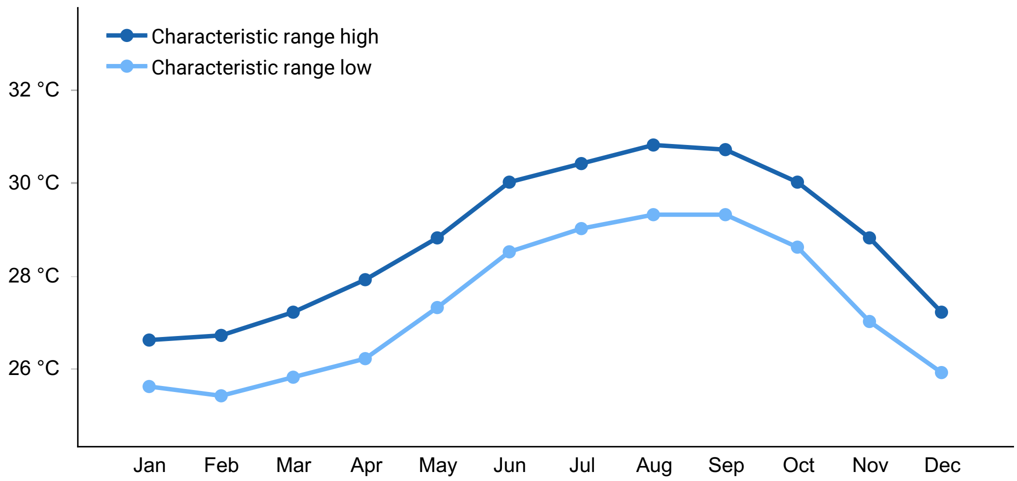

Figure 3. Monthly maximum temperature range

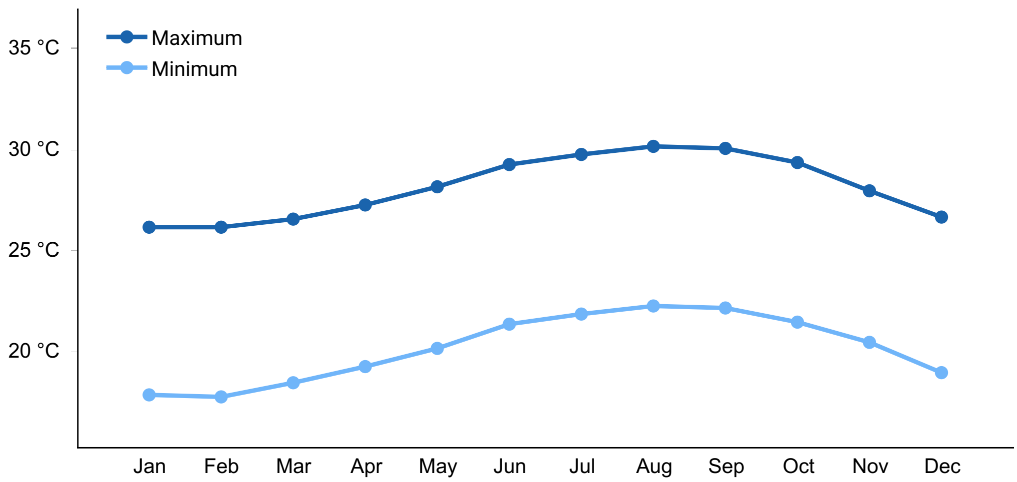

Figure 4. Monthly average minimum and maximum temperature

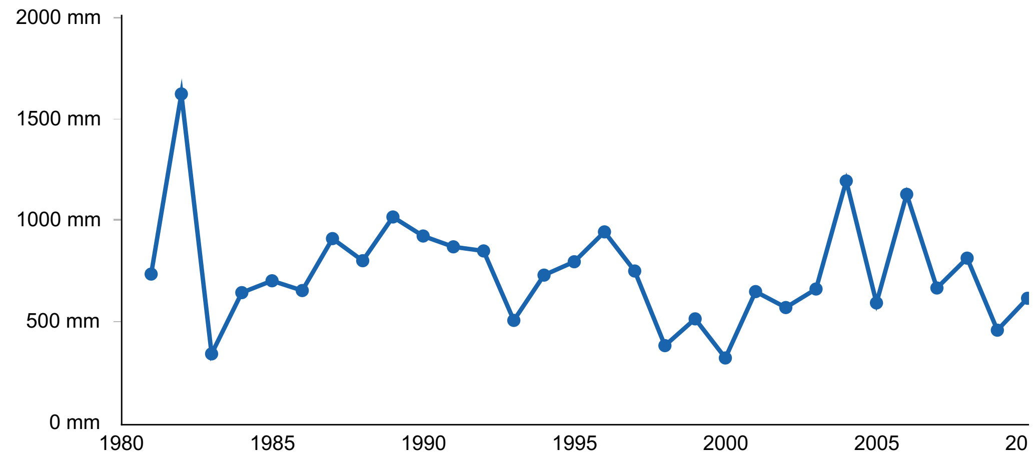

Figure 5. Annual precipitation pattern

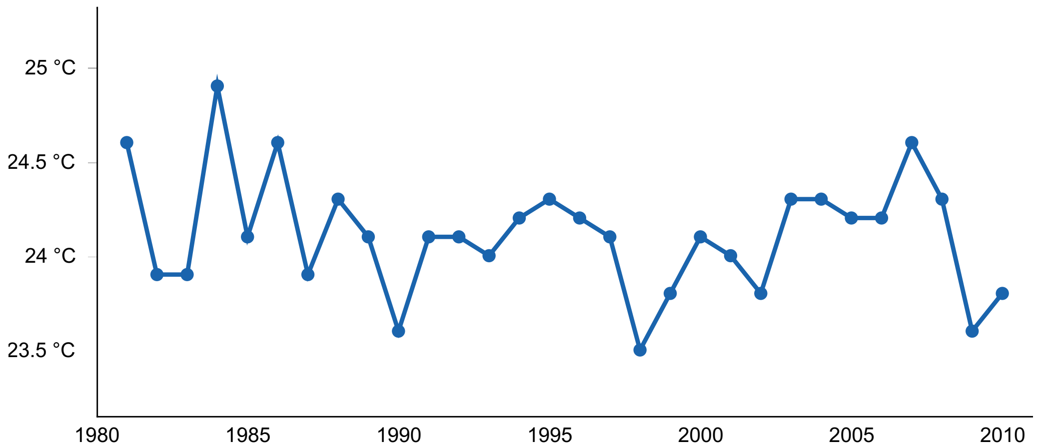

Figure 6. Annual average temperature pattern

Climate stations used

- (1) WAIMEA 947 [USC00519629], Kekaha, HI
- (2) BARKING SANDS [USW00022501], Kekaha, HI
- (3) WAIKIKI 717.2 [USC00519397], Honolulu, HI
- (4) KII-KAHUKU 911 [USC00514500], Kahuku, HI
- (5) PRINCEVILLE RCH 1117 [USC00518165], Princeville, HI

Influencing water features

This ecological site is associated with areas of permanent open water. Some open water is due to sites being diked or impounded. Only two soil components, Kaloko noncalcareous variant and Keeau, extend to tidal, saltwater, estuarine areas. Most sites are described in the National Wetland Inventory (NWI) as palustrine (small, shallow, non-saline, without wave-formed or bedrock shorelines). Kaloko and Keeau clay range from palustrine to estuarine (USFWS, 2023).

Number of National Wetland Inventory (NWI) features overlapping ecological site: freshwater emergent wetlands (541), freshwater pond (196), riverine (126), freshwater forested/shrub wetland (80), estuarine and marine wetland (62), and estuarine and marine deepwater (26) (USFWS, 2023).

Number of National Hydrologic Dataset (NHD) features overlapping ecological site: lake/pond (54), reservoir (16), stream/river (16), swamp/marsh (16), sea/ocean (2), and foreshore (1) (USGS, 2019).

Soil features

The soil components associated with this ecological site are Kaloko, Kaloko drained variant, Kaloko noncalcareous variant, Keaau, Mokuleia poorly drained variant, Nohili, and Pearl Harbor.

Most of the soils in this ecological site are Endoaquolls. These are soils with a dark surface horizon high in organic matter and base cations, an aquic soil moisture regime (in which the soil is free of dissolved oxygen because it is saturated by water), and a regional water table that is at or near the soil surface for extended periods. Most of the soils have a year-round warm soil temperature regime (isohyperthermic). All are moderately deep to very deep and poorly or very poorly drained. They formed in alluvium over calcareous materials (marl, coral sand, or limestone), except for two soils noted below. Surface horizons from 0 to 10 inches (0 to 254 millimeters) have pH values ranging from 6.7 to 7.9 while pH values from 10 to 20 inches (254 to 508 millimeters) range from 6.7 to 8.5 (USDA-SCS, 1972).

Mokuleia is an Aquic Haplustolls. Aquic Haplustolls are mainly in depressions or on flood plains (USDA-SCS, 1972).

While water table depths typically range from 18 to 48 inches (46 to 122 centimeters), two are greater than 72 inches (183 centimeters). Some soils have deeper permanent water tables indicated by gleyed conditions. The high pH of some of these soils may hinder development of hydric indicators (USDA-SCS, 1972).

Kaloko noncalcareous variant soils developed in alluvium over noncalcareous material, unlike the other phases of this soil series. It is sometimes ponded on the surface (details not in Soil Survey) and is gleyed from the surface to the bottom of the soil profile, indicating persistent saturation and anaerobic conditions (USDA-SCS, 1972).

Pearl Harbor soils developed in alluvium deposited over, and mixed with, muck or peat. It is classified as thapto-histic, meaning the soil profile contains a buried organic horizon within 40 inches (102 centimeters) of the mineral soil surface (USDA-SCS, 1972).

Many of the former wetlands have been drained and are used for homesites, urban development, pasture, or crops. This is particularly the case for Kaloko and Nohili on Kauai.

Adjoining the soils described above are areas mapped as Marsh; it is not mapped as a soil series but rather is called a Miscellaneous Area. By definition, they have little or no soil and support little or no vegetation. However, in the Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii upon which this ecological site is based, Miscellaneous Areas are extensive, and most and were mapped by low-intensity reconnaissance methods that provide less-detailed information than that presented for soil series and their phases. In many cases and especially this one, Miscellaneous Areas in Maui, Molokai, Lanai, Oahu, and Kauai are well-vegetated and/or contain plant and animal species of interest to conservationists (USDA-SCS, 1972). Marsh is described in the following paragraphs.

Complete soil information is not available for Marsh. They occur on Kauai and Oahu, where they often abut or intermingle with the soil series of this ecological site. They also occur on Molokai, on which this ecological site does not occur. Marsh soils are likely poorly drained soils consisting of a peat layer over mineral layers of coral rubble, shell fragments, or alluvial sand and silt. Soils may be periodically flooded. Ponding may occur in low areas after heavy rainfall or high tides; upon drying, salt crystals may accumulate on the surface to produce a bare, unvegetated spot.

Waters are brackish to fresh, depending on proximity to the ocean. Elevations are 0 to 40 feet (0 to 12 meters) above sea level. Annual air temperatures, wetness, and proximity to the ocean are associated with very warm (isohyperthermic), water-saturated and anaerobic (aquic), and, in places, elevated salinity conditions. Representative annual rainfall averages 20 to 46 inches (508 to 1,168 millimeters). Vegetation consists of a mix of sedges, grasses, forbs, and a species of fern. Many of the characteristic plant species are adapted to ranges of salinity, enabling them to occupy wide areas along the salinity gradient (USDA-SCS, 1972).

Table 5. Representative soil features

Parent material	(1) Alluvium–igneous rock
Surface texture	(1) Clay loam (2) Clay (3) Stony clay
Family particle size	(1) Very-fine (2) Fine (3) Clayey over sandy or sandy-skeletal
Drainage class	Very poorly drained to poorly drained
Permeability class	Very slow to moderately slow
Depth to restrictive layer	86–183 cm
Soil depth	86–183 cm
Surface fragment cover <=3"	0%

Surface fragment cover >3"	0%
Available water capacity (0-101.6cm)	10.16–15.24 cm
Calcium carbonate equivalent (0-101.6cm)	0–100%
Electrical conductivity (0-101.6cm)	0–32 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0–1
Soil reaction (1:1 water) (0-25.4cm)	6.7–7.9
Subsurface fragment volume <=3" (0-101.6cm)	2–7%
Subsurface fragment volume >3" (0-101.6cm)	0–5%

Table 6. Representative soil features (actual values)

Drainage class	Very poorly drained to somewhat poorly drained
Permeability class	Not specified
Depth to restrictive layer	Not specified
Soil depth	Not specified
Surface fragment cover <=3"	Not specified
Surface fragment cover >3"	Not specified
Available water capacity (0-101.6cm)	Not specified
Calcium carbonate equivalent (0-101.6cm)	Not specified
Electrical conductivity (0-101.6cm)	Not specified
Sodium adsorption ratio (0-101.6cm)	0–10
Soil reaction (1:1 water) (0-25.4cm)	Not specified
Subsurface fragment volume <=3" (0-101.6cm)	Not specified
Subsurface fragment volume >3" (0-101.6cm)	Not specified

Ecological dynamics

The information in this ecological site description (ESD), including the state-and-transition model (STM), was developed using archaeological and historical data, professional experience, and scientific studies. The information is representative of a complex set of plant communities. Not all scenarios or plants are included. Key indicator plants, animals, and ecological processes are described to inform land management decisions. The nature and extent of these wetlands prior to the arrival of humans in Hawaii is not clearly known.

Natural Disturbances

The natural (not human-related) disturbances most important for discussion in this ecological site are changes in water salinity and alteration in water depth and the shoreline.

Long periods of unusually high rainfall or drought may cause changes in groundwater depth and salinity that differentially affect range, abundance, and productivity of the plant species occurring on a site. Long-term changes in sea levels will have similar effects.

Human Disturbances

Approximately 24 percent (1,937 acres) of this 8,228-acre ecological site overlaps with the Lincoln et al., (2023) modeled Flooded Pondfields agroecological systems (Lincoln et al., 2023).

Early Polynesian settlers altered wetlands and open water bodies for agriculture, yet many wetlands remained intact. "Many low elevation freshwater wetlands (flooded pondfields) were used for production of coco yam (*Colocasia esculenta*) and taro or kalo (Alocasia sp.) (Lincoln et al., 2023). These pondfields, known as lo‘i in Hawaii, were the preferred agricultural features wherever suitable areas of flat land were accessible by the gravitational flow of water. With the use of water diversions, other crops were also grown in and near the lo’i." Forests above these wetlands may have been removed partly to encourage erosion of soils into low wetland areas used for taro cultivation (Kirch, 1982).

The arrival of Westerners beginning in 1778 brought many changes to the islands. The establishment of sugarcane plantations around 1835 led to extensive stream diversions into ditches, tunnels, flumes, and reservoirs. Many taro patches were converted to rice paddies. Evidence indicates accelerated and extensive deforestation, erosion, siltation, and changes in local weather patterns (Kirch, 1983) due to more intensive land use. This would have caused movement and accumulation of soils that may have altered the substrates along the coast.

Red mangrove (*Rhizophora mangle*) was introduced to Molokai in 1902 with the intent of stabilizing mud flats. Stands of this species have greatly altered the ecology of coastal wetlands, primarily in saline and brackish areas and to some extent in freshwater areas

(Allen, 1998).

Cattle, sheep, horses, goats, and larger European pigs were introduced in the final decades of the 18th century. These animals ranged free on the islands, becoming very numerous and destructive by the early decades of the 19th century. By 1851, records reported severe overstocking of pastures, lack of fences, and large numbers of feral livestock (Henke, 1929). This would have resulted in consumption of native plants and physical disturbance of sites by wallowing and hoof action.

The heaviest impacts in this ecological site have been caused by dredging, filling, and urbanization. From the early 1900s, the lowland wetlands along the coast were filled or otherwise modified. An example of this is the development of Pearl Harbor. At this time, Waikıkı was a marsh. By 1920, it was drained and filled with dredge material from the Ala Wai Drainage Canal. Much of the former wetland area in Hawaii has been developed for urban use (Kirch, 1983).

State and transition model

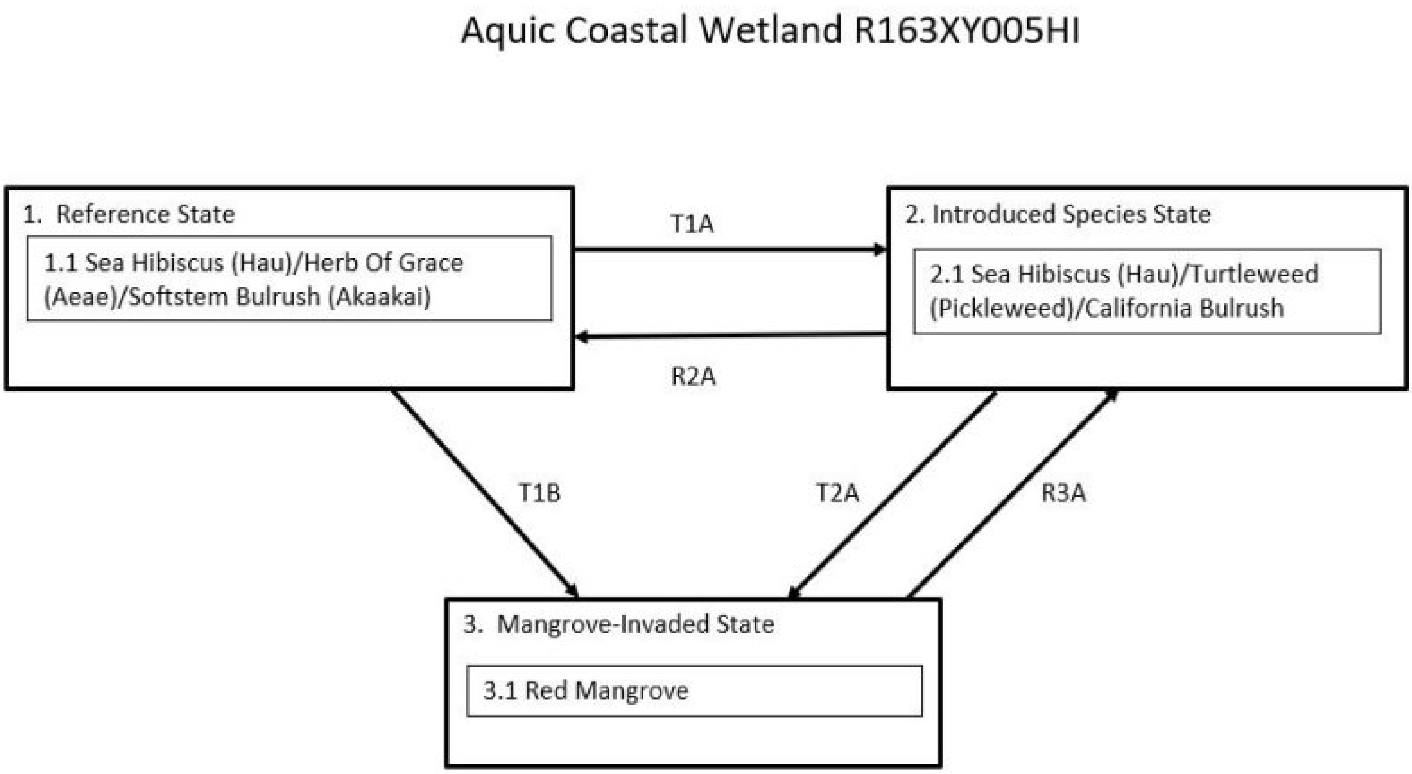

Figure 7. State-and-transition model diagram for the Aquic Coastal Wetland (R163XY005HI).

State 1
Reference State

The Reference State (1) consists of one historical community phase. Few if any examples of this historical state remain. The concept of this site may encompass more than one wetland type, but because there are few intact sites to study, and because all wetlands have been drained from some soil series or phases, a range of variation is included.

Gradual invasion by introduced herbaceous plant species results in a transition to the Introduced Species State (2). Gradual invasion by mangroves results in a transition to the Mangrove-Invaded State (3).

Community 1.1
Hau (Sea Hibiscus)/Aeae (Herb Of Grace)/Akaakai (Softstem Bulrush)

This historical community phase varies somewhat in abundance of trees, forbs, and rushes and sedges. In many sites there is a salinity gradient from salt water through brackish to fresh water. Different species tolerate different salinity ranges, creating a gradual and overlapping change in species composition along the gradient. Dominant species typically are the tree sea hibiscus or hau (*Hibiscus tiliaceus*), the forbs herb of grace or aeae (*Bacopa monnieri*) and shoreline seapurslane or akulikuli (*Sesuvium portulacastrum*), cosmopolitan bulrush or kaluha (*Bolboschoenus maritimus*), softstem bulrush or akaakai (*Schoenoplectus tabernaemontani*), and smooth flatsedge or makaloa (*Cyperus laevigatus*). Another kaluha (*Schoenoplectus californicus*), known in the Plants Database as California bulrush, may be an introduced or indigenous species. Jamaca swamp sawgrass or uki (Cladium jamaicense), other sedge species (Cyperus, Scleria, and Fimbristylis), and seashore dropseed or akiaki (*Sporobolus virginicus*), a grass, may be present. Also occurring are a fern, willdenow's maiden fern or neke (*Thelypteris interrupta*), and a vine, Brazilian bayhops or pohuehue (*Ipomoea pes-caprae* ssp. brasiliensis) (Browning et al., 2019; Elliott, 1981; Wagner et al., 1999).

Dominant plant species

- sea hibiscus (*Hibiscus tiliaceus*), shrub
- softstem bulrush (*Schoenoplectus tabernaemontani*), grass
- herb of grace (*Bacopa monnieri*), other herbaceous

State 2
Introduced Species State

The Introduced Species State (2) consists of one community phase. It differs from the Reference State (1) by containing fewer or less abundant native plant species due to invasion by introduced plant species. In many cases, the vegetation is similar to Reference State (1) with regard to plant families, plant statures, and functions of the community with regard to wildlife habitat. In some cases, dominance by introduced herbaceous species may alter these conditions and functions.

Community 2.1
Sea Hibiscus (Hau)/Turtleweed (Pickleweed)/California Bulrush

This community phase may contain sea hibiscus trees (hau) trees. The herbaceous layer typically has dense stands of turtleweed (pickleweed) and grasses or grasslike plants. Many of the native species from the Reference State (1) may still be present and abundant. California bulrush or Kaluha (*Schoenoplectus californicus*), which may be introduced or indigenous, is often codominant. Some other common sedges are Canada spikesedge (*Eleocharis geniculata*) and umbrella plant or ahuawa haole (*Cyperus involucratus*). The introduced forbs turtleweed or pickleweed (*Batis maritima*), climbing dayflower or honohono (*Commelina diffusa*), and Mexican primrose-willow or kamole (*Ludwigia octovalvis*) and the introduced shrub Indian camphorweed or Indian fleabane (*Pluchea indica*) may be present (Browning et al., 2019; Elliott, 1981; Wagner et al., 1999). Grass species are more common than in the Reference State (1), and some species, especially para grass or Californiagrass (*Urochloa mutica*), can grow to create tall, dense, single species stands in freshwater areas; this can reduce the value of the wetland for water bird habitat.

Dominant plant species

- sea hibiscus (*Hibiscus tiliaceus*), shrub
- California bulrush (*Schoenoplectus californicus*), grass
- turtleweed (*Batis maritima*), other herbaceous

State 3
Mangrove-Invaded State

The Mangrove-Invaded State (3) is dominated by red mangroves (*Rhizophora mangle*), a medium-sized tree that has replaced all or part of the herbaceous vegetation that dominates the Reference State (1) and the Introduced Species State (2). Sea hibiscus or Hau trees are not present.

Community 3.1
Red Mangrove

This community is dominated or heavily populated by red mangrove (*Rhizophora mangle*). Mangroves primarily inhabit saline and brackish areas but can establish to some extent in freshwater areas. This species is a shrubby tree that grows to 33 feet (10 meters) tall that has stems supported by numerous branched stilt roots. It can form impenetrable thickets that exclude other species, completely changing the nature of the wetland and reducing the wildlife habitat value of a marsh. Control of mangroves is primarily done by mechanical means, either with machinery where possible or by hand-held chainsaws. Removal by these methods is extremely expensive (Allen, 1998).

Dominant plant species

- red mangrove (*Rhizophora mangle*), tree

Transition T1A
State 1 to 2

The Reference State (1) transitions to the Introduced Species State (2) by gradual invasion and replacement of native species by introduced plant species.

Transition T1B
State 1 to 3

The Reference State (1) transitions to the Mangrove-Invaded State (3) by gradual invasion and replacement of native and introduced herbaceous species by mangroves.

Restoration pathway R2A
State 2 to 1

It may not be feasible to restore the Introduced Species State (2) to the Reference State (1) due to the intermixing of introduced and native species and the unknown provenance of some species. It is worthwhile in some cases to reduce the abundance of weedy species and reintroduce native plant species where the wildlife habitat functions of the marsh have been degraded.

Transition T2A
State 2 to 3

The Introduced Species State (2) transitions to the Mangrove-Invaded State (3) by gradual invasion and replacement of herbaceous stands by woody mangroves.

Restoration pathway R3A
State 3 to 2

Mechanical or hand methods can be employed to remove mangroves and reestablish herbaceous vegetation.

Additional community tables

Other references

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DEFINITIONS

These definitions have been greatly simplified for brevity and do not cover every aspect of each topic.

Alluvial: Materials or processes associated with transportation and/or deposition by running water.

Aquic soil moisture regime: A regime in which the soil is free of dissolved oxygen because it is saturated by water. This regime typically exists in bogs or swamps.

Aridic soil moisture regime: A regime in which defined parts of the soil are, in normal years, dry for more than half of the growing season and moist for less than 90 consecutive days during the growing season. In Hawaii it is associated with hot, dry areas with plants such as kiawe, wili wili, and buffelgrass. The terms aridic and torric are basically the same.

Available water capacity: The amount of soil water available to plants to the depth of the first root-restricting layer.

CaCO3 equivalent: The amount of free lime in a soil. Free lime exists as solid material and typically occurs in regions with a dry climate.

Community pathway: A description of the causes of shifts between community phases. A community pathway is reversible and is attributable to succession, natural disturbances, short-term climatic variation, and facilitating practices, such as grazing management.

Community phase: A unique assemblage of plants and associated dynamic soil properties within a state.

Dominant species: Plant species or species groups that exert considerable influence upon a community due to size, abundance, or cover.

Drainage class: The frequency, duration, and depth of a water table in a soil. There are seven drainage classes, ranging from “excessively drained” (soils with very rare or very deep water tables) to “well drained” (soils that provide ample water for plant growth but are not so wet as to inhibit root growth) to “very poorly drained” (soils with a water table at or near the surface during much of the growing season that inhibits growth of most plants).

Electrical conductivity (EC): A measure of the salinity of a soil. The standard unit is deciSiemens per meter (dS/m), which is numerically equivalent to millimhos per centimeter (mmhos/cm). An EC greater than about 4 dS/m indicates a salinity level that is unfavorable to growth of most plants.

Gleyed: A condition of soil from which iron has been reduced (in the redox chemistry sense) and removed during soil formation or that saturation with stagnant water has preserved a reduced state. If iron has been removed, the soil is the color of uncoated sand and silt particles. If iron is present in a reduced state, the soil is the color of reduced iron (typically bluish-gray). Redox concentrations (spots of oxidized iron, formerly called mottles are often present.

Isohyperthermic soil temperature regime: A regime in which mean annual soil temperature is 72 degrees F (22 degrees C) or higher and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Major Land Resource Area (MLRA): A geographic area defined by NRCS that is characterized by a particular pattern of soils, climate, water resources, and land uses. The island of Hawaii contains nine MLRAs, some of which also occur on other islands in the state.

Mollisols: Soils with relatively thick, dark surface horizons, high cation-exchange capacity, high calcium content, that do not become hard or very hard when dry. Mollisols are conducive to plant growth. They characteristically form under grass in climates that are seasonally dry, but can form under forests.

Naturalized plant community: A community dominated by adapted, introduced species. It is a relatively stable community resulting from secondary succession after disturbance.

Most grasslands in Hawaii are in this category.

Parent material: Unconsolidated and chemically weathered material from which a soil is developed.

pH: The numerical expression of the relative acidity or alkalinity of a soil sample. A pH of 7 is neutral; a pH below 7 is acidic and a pH above 7 is basic.

Reference community phase: The phase exhibiting the characteristics of the reference state and containing the full complement of plant species that historically occupied the site. It is the community phase used to classify an ecological site.

Reference state: A state that describes the ecological potential and natural or historical range of variability of an ecological site.

Restoration pathway: A term describing the environmental conditions and practices that are required to recover a state that has undergone a transition.

Sodium adsorption ratio (SAR): A measure of the amount of dissolved sodium relative to calcium and magnesium in the soil water. SAR values higher than 13 create soil conditions unfavorable to most plants.

Soil moisture regime: A term referring to the presence or absence either of ground water or of water held at a tension of less than 1,500 kPa (the crop wilting point) in the soil or in specific horizons during periods of the year.

Soil temperature regime: A defined class based on mean annual soil temperature and on differences between summer and winter temperatures at a specified depth.

Soil reaction: Numerical expression in pH units of the relative acidity or alkalinity or a soil.

State: One or more community phases and their soil properties that interact with the abiotic and biotic environment to produce persistent functional and structural attributes associated with a characteristic range of variability.

State-and-transition model: A method used to display information about relationships between vegetation, soil, animals, hydrology, disturbances, and management actions on an ecological site.

Torric soil moisture regime: See Aridic soil moisture regime.

Transition: A term describing the biotic or abiotic variables or events that contribute to loss of state resilience and result in shifts between states.

Ustic soil moisture regime: A regime in which moisture is limited but present at a time when conditions are suitable for plant growth. In Hawaii it usually is associated with dry forests and subalpine shrublands.

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Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	03/29/2026
Approved by	Kendra Moseley
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

2. **Presence of water flow patterns:**

3. **Number and height of erosional pedestals or terracettes:**

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**

5. **Number of gullies and erosion associated with gullies:**

6. **Extent of wind scoured, blowouts and/or depositional areas:**

7. **Amount of litter movement (describe size and distance expected to travel):**

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**

9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**

12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

    Dominant:

    Sub-dominant:

    Other:

    Additional:

13. **Amount of plant mortality and decadence (include which functional groups are**

expected to show mortality or decadence):

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14. **Average percent litter cover (%) and depth (in):**

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15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**

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16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

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17. **Perennial plant reproductive capability:**
