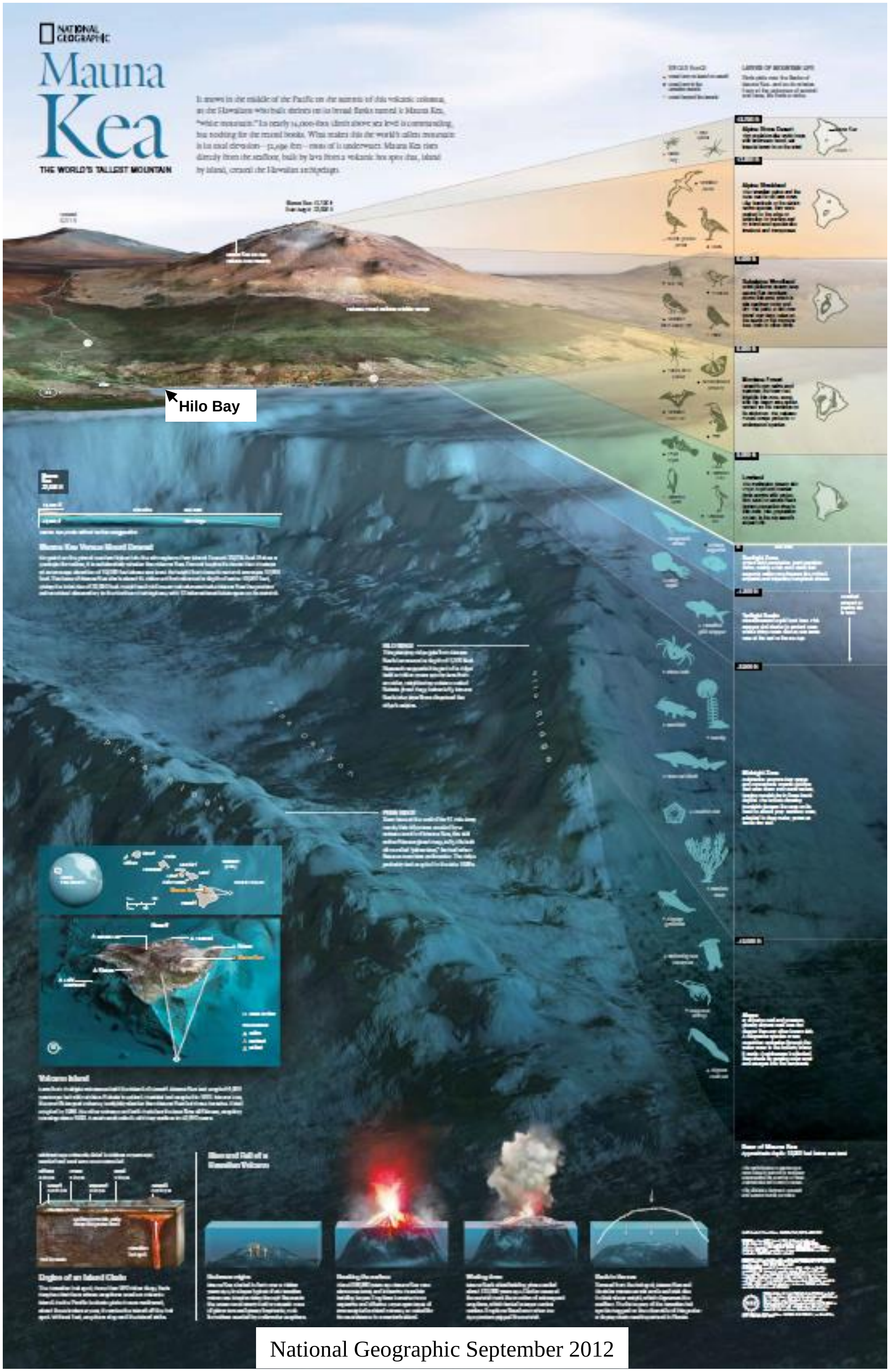
HILO BAY MULIWAI

NATIONAL ESTUARINE RESERVE SYSTEM SITE DESIGNATION FOR HAWAI‘I STATE



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EXECUTIVE SUMMARY

Hilo Bay *muliwai* (estuary) is an ideal site for a National Estuarine Research Reserve System (NERRS) site. Its watershed drains the windward sides of the Earth's tallest (from seafloor to summit) and most massive mountains, Mauna Kea and Mauna Loa, respectively. This watershed has one of the highest precipitation rates in the Hawaiian Islands and in the United States, with annual rainfall ranging from 50 cm near shore to 600 cm at higher elevations. Hence, the amount of freshwater entering Hilo Bay from surface flow and groundwater is greater than any other Hawaiian estuary; therefore the gradients observed within the system cannot be matched elsewhere in the state. Hilo Bay's watershed is the largest in Hawaiʻi State, and its surface water inputs are dominated by two rivers, the Wailuku River watershed to the north, and the Wailoa River watershed to the south. The Wailuku River watershed encompasses 653 km^2 with headwaters starting near 4,200 m in elevation on the slopes of Mauna Kea. The Wailoa River watershed encompasses 255 km^2 with headwaters starting near 2964 m in elevation on the slopes of Mauna Loa. Both the Wailuku and Wailoa Rivers' watersheds are dominated by evergreen forest (50%), much of which is native vegetation above 2,500 m and within the conservation land use category (over 70%). Greater than 50% of the land within the proposed site boundaries, the majority of the forested area, is categorized as Watershed Restoration Priority I Area according to the Department of Land and Natural Resources '*The Rain Follows the Forest*' initiative and is home to16 animals and 24 plants that are classified as either endangered, threatened, or candidates for listing. The majority of the land (76%) within the proposed site is publically owned by the Hawaiʻi County, Hawaiʻi State, or Federal Government, and most of it is managed within the Hawaiʻi reserves and parks system and can be easily accessed by hiking or 4X4 vehicles.

The water body boundaries the Hilo Bay *muliwai* NERRS span from Honoliʻi Cove to Keaukaha, and includes two of the three estuary types found in Hawaiʻi State: 1) estuaries at the mouth of streams and rivers and 2) locations where streams are absent, but coastal groundwater discharges abundantly near shore. This proposed site has all three ecosystem types listed in the NERRS Program Regulations (15 CFR Part 921): shorelands, transitional areas, and submerged bottoms, and within each ecosystem type, most subcategories are represented. The majority of the coastline in is comprised of 15 state and county parks, and includes the longest black sand beach in the state and a small boat harbor. The Hilo Harbor is enclosed by a historic 3-km long breakwater running, which reduces wave energy and minimizes mixing between freshwater and saltwater layers; this creates favorable conditions for phytoplankton blooms and trapping watershed-derived materials. Outside the breakwater, there are several coral reef and rocky intertidal areas, as well as unique habitats like anchialine ponds and traditional, working fish ponds. Four endangered and threatened marine species are found within the proposed site boundaries: humpback whales, hawksbill and green sea turtles, and Hawaiian Monk seals. This water body is also important juvenile habitat for several native and endemic fish [striped mullet ('*ama 'ama*), flagtail (*aholehole*), giant trevally (*ulua*), goatfish (*weke*), and bigeyed scad (*akule*)] and a nursery for black-tipped and scalloped hammerhead sharks. It is also considered a critical habitat for the stripped mullet recreational fishery.

Educational groups from the University of Hawaiʻi at Hilo (UHH) and Hawaiʻi Community College, as well as from the 26 local public and private schools, including a Hawaiian immersion school, use this system as a '*natural laboratory'* that cannot be match anywhere else on Earth. There are also many enrichment programs available to these 16,000

students through organizations and centers like Edith Kanakaʻole Foundation, Three Mountain Alliance Watershed Partnership, ʻImiloa Astronomy Center, and NOAA Mokupāpapa Discovery Center that marry culture, environment, and research. UHH is also adding to the information foundations of these organizations and previous studies through its blossoming research program and its *in situ* sensors that include a real-time water quality buoy and two high frequency radar arrays. This instrumentation complements a PacIOOS wave buoy located just outside Hilo Bay, as well as the two NOAA rainfall and USGS river discharge (Wailuku and Honoliʻi) gages. With the historic knowledge base, *in situ* instrumentation, and diversity of land use within the Hilo Bay watershed, most of Hawaiʻi State's Coastal Zone Management (CZM) initiatives can be addressed using Hilo Bay and its watershed as a model system. Therefore, designation of Hilo Bay *muliwai* as a NERRS site will aid in consolidating the existing cultural, educational, and research-based activities, as well as developing new ones in program areas not addressed yet, and will allow for conservation of one of the Earth's most spectacular watersheds.

THE HILO BAY MULIWAI HUI

Muliwai is the Hawaiian word for estuary.
Hui is the Hawaiian word for group.

1. Edith Kanaka'ole Foundation (EKF). EKF is a non profit 501 C(3) whose mission is to teach and encourage heightened indigenous Hawaiian cultural awareness and participation through Hawaiian cultural education and the maintenance of the teachings, beliefs, practices, philosophies, and traditions of Edith and Luka Kanakaʻole. EKF is instrumental in the revival of cultural management practices through the understanding of Papaku Makawalu, an ancient method of understanding our environment taught to us through the Kumulipo or the Hawaiian story of creation. **Represented by:** Roxane Stewart and Kala Mossman.

2. University of Hawaiʻi at Hilo (UHH). UHH's mission begins with the wise saying *ʻAʻohe pau ka ʻike i ka hālau hoʻokahi. One learns from many sources.* The purpose of our university ʻohana (family) is to challenge students to reach their highest level of academic achievement by inspiring learning, discovery and creativity inside and outside the classroom. Our kuleana (responsibility) is to improve the quality of life of the people of Hawaiʻi, the Pacific region and the world. UHH has a total enrollment of 4,139 students and is comprehensive university, with an emphasis on undergraduate education (85% of students), and a developing graduate studies program (15% of students). **Represented by:** Tracy Wiegner (Marine Science), Steven Colbert (Marine Science), Noe Puniwai (PIPES), Sharon Ziegler-Chong (PIPES), and Jason Adolf (Marine Science).

3. Division of Aquatic Resources (DAR), Department of Land and Natural Resources, State of Hawaii. DAR manages the state's aquatic resources and ecosystems through programs in commercial fisheries and resource enhancement; aquatic resources protection, habitat enhancement, and education; and recreational fisheries. In particular, projects conducted by DAR and its staff in Hilo focus on the assemblage, life history and biology of estuarine fishes throughout Hawaii, estuarine habitat characterization, and the impacts of alien plant and animal species on native estuarine fishes. The principal goal of such projects is to understand fundamental biological patterns and ecological dynamics in Hawaiian estuaries, which will ultimately improve management efforts that sustain and enhance coastal fisheries and estuarine resources throughout the state. **Represented by:** Troy Sakihara.

4. Mauna Kea Watershed Alliance (MKWA). The MKWA brings together major landowners on Mauna Kea around a shared interest to protect ʻāina by working together to manage threats that occur across common land ownership boundaries, pooling limited resources to achieve conservation goals, and promoting collaboration in protecting vital resources across large landscapes. The vision of the MKWA is to protect and enhance watershed ecosystems, biodiversity and resources through responsible management, while promoting economic sustainability and providing recreational, subsistence, educational and research opportunities. The MKWA management boundary encompasses 534,221 GIS (Geographic Information Systems) acres, 2/3's of which are partnership lands. Our signed partners include the Department of Land and Natural Resources, Department of Hawaiian Home Lands, Kamehameha Schools, Hakalau Forest and National Wildlife Refuge, and Kukaʻiau Ranch. Our affiliate partners include The Nature Conservancy, US Fish and Wildlife Service - Pacific Islands Fish and Wildlife Office, and the USDA Forest Service - Institute of Pacific Islands Forestry. **Represented by:** Cheyenne Perry.

5. Three Mountain Alliance (TMA). The TMA(originally known as the ʻŌlaʻa Kīlauea Partnership) was formed in 2007 and is the State's largest watershed partnership covering 1,116,300 acres. With 9 partners, the overall goal of the TMA is to sustain the multiple ecosystem benefits of the three mountains of Kīlauea, Mauna Loa, and Hualālai by responsibly managing its watershed areas, native habitats and species, historical, cultural, and socio-economic resources for all who benefit from the continued health of the three mountains. ʻImi Pono no ka ʻĀina (ʻImi Pono) is the environmental education and out-reach program for the TMA watershed partnership. Since its creation 1999, the program has provided conservation-themed programs for students and teachers, led community service trips, and participated at community events across Hawaiʻi Island. The diversity of native landscapes within the TMA provides unparalleled opportunities for individuals to learn about and experience the ecosystems that undoubtedly sustain life here in Hawaiʻi. Coupled with cultural and scientific knowledge, practices, and activities, ʻImi pono strives to provide meaningful experiences that create and strengthen the relationship between man and nature. **Represented by:** Lahela Camara

6. NOAA Mokupāpapa Discovery Center (MCD). MDC is the primary educational facility for the Papahānaumokuākea Marine National Monument. The center was established in 2003 to interpret the natural science, culture, and history of the Northwestern Hawaiian Islands. The goal of the center is to "bring the place to the people" and spur greater public awareness of the region and relevant ocean conservation issues. The center receives an average of 60,000 visitors per year, with approximately half of these being local residents and the other half visiting from elsewhere. **Represented by:** Kalewa Correa, Nakoa Goo, Etta Karth, and Tim Brown.

7. Conservation International Hawai`i Fish Trust. The purpose of Conservation International's Hawai'i Fish Trust is to restore near-shore seafood security through strategic partnerships and focused investment for the well-being of Hawai'i and its people. Conservation International partners with local fishing communities, businesses, non-profit organizations and the State of Hawai'i to facilitate the sustainable management of Hawai'i's near-shore fisheries. **Represented by:** Luka Mossman

SITE NARRATIVE

I. Justification for site boundaries. The proposed boundaries for the Hilo Bay National Estuary Research Reserve System (NERRS) site include the Hilo Watershed, Hawai'i Hydrologic Unit Code (HUC) – 2001000003 developed by the USDA NRCS, as well as a portion of coastal Hilo lands defined by *ahupua'a* (land division) (Fig. 1). The ocean coastline of the project area was buffered to 2 miles for the purposes of watershed management. The proposed *'Āina Kumu Wai o Hilo* (*kumu wai*) project area is a hybrid of the *ahupua'a* (land division) system and Hilo Watershed Hydrologic Unit. It combines traditional approaches with the current watershed assessment to more effectively conserve and mange natural and cultural resources within the Hilo watershed. The *kumu wai* project area encompasses intact native forested lands essential to ensure both good water quantity and quality for healthy estuaries. The approach is comprehensive and holistic. The boundaries taken into account the connectivity among the terrestrial, coastal, and ocean ecosystems and their communities and functions that are dependent on it.

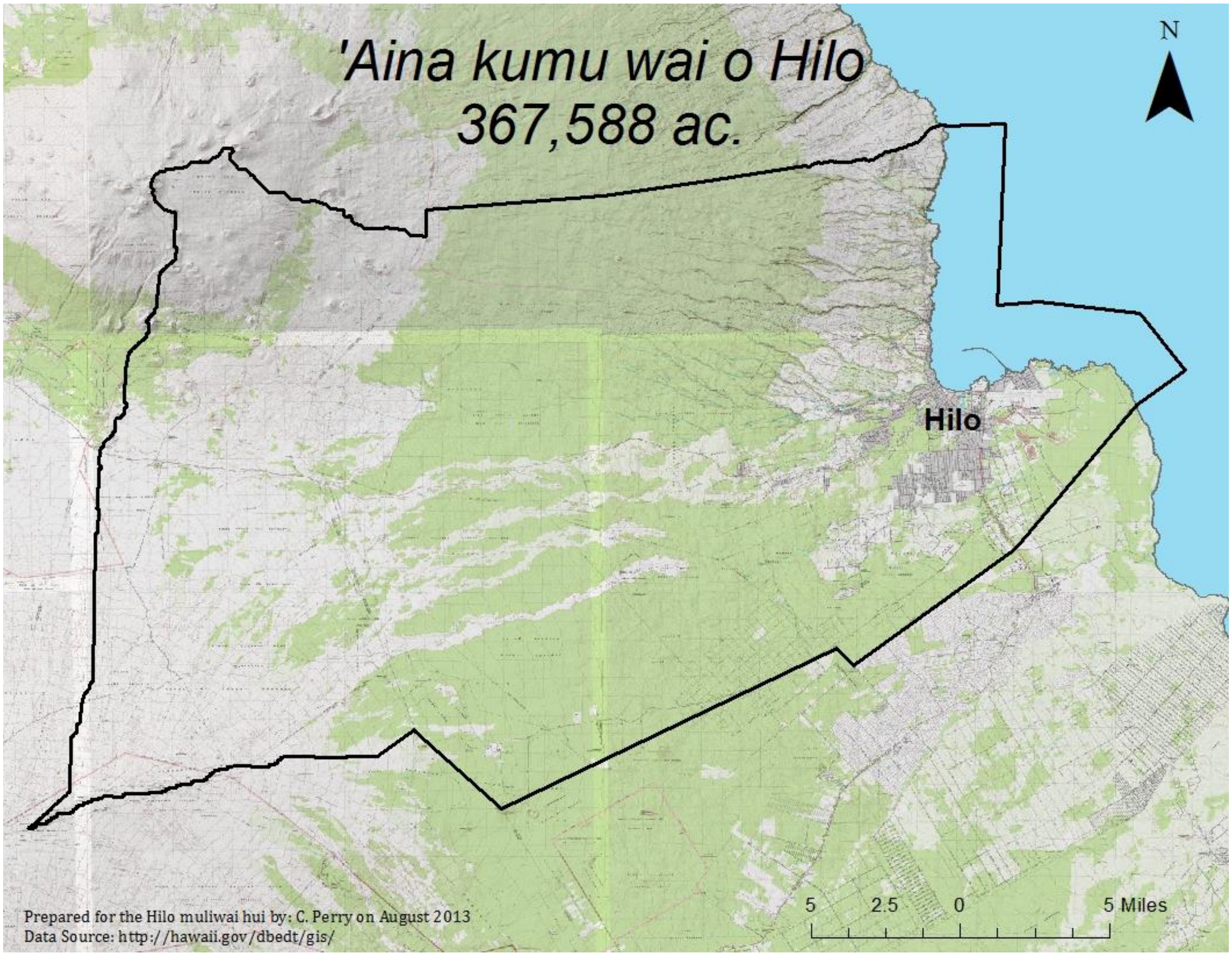


Figure 1. Proposed boundaries for the Hilo Bay *muliwai* National Estuarine Research Reserve System (NERRS) site.

II. Environmental Representativeness: Ecosystem/Ecological Characteristics

A. Ecosystem Composition.

1. Coastal. Within the proposed reserve boundaries for Hilo Bay *muliwai*, there is a diversity of marine ecosystem types and physical characteristics of high value for research, education, protection, and management. Of the 'Ecosystem Type' designations listed in Appendix 2 of NERRS Program Regulations (15 CFR Part 921), this proposed site has all three ecosystem types: shorelands, transitional areas and submerged bottoms. Within each of these ecosystem types, most of the subcategories are represented; they include: 1) Shorelands –coastal cliffs: (Hilo Pali-ku), 2) transitional areas –Coastal marshes, Intertidal Rocky Areas, Intertidal Beaches, and Intertidal Algal Bed, and 3) Submerged Bottoms –Subtidal Hard Bottoms, Subtidal Soft Bottoms, and Subtidal Plants and Coral (Fig. 2).

Figure 2. Ecosystem types found in Hilo Bay Muliwai: A) coastal cliffs, B) coastal marshes, C) intertidal rocky areas, D) intertidal beaches, E) intertidal algal beds, F) subtidal hard bottoms, G) subtidal soft bottoms, and H) subtidal plants and corals.

2. Forest. According to the USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment (2009), the Hilo watershed is primarily evergreen forest (48%), with other shrub and grasslands accounting for another 34% (Fig. 3). Bare lands from recent lava flows represent 16% of the area and developed and cultivated lands account for only 3%. These forested lands are primarily natural areas with fair to very good ecosystem viability and much of the lands have been identified as forest bird recovery habitat, as well as important areas for threatened and endangered native Hawaiian invertebrate, terrestrial mammal, bird, and plant species. According to The Nature Conservancy (TNC; 2008), ~70% of the Hilo watershed has retained its native-dominated ecosystems.

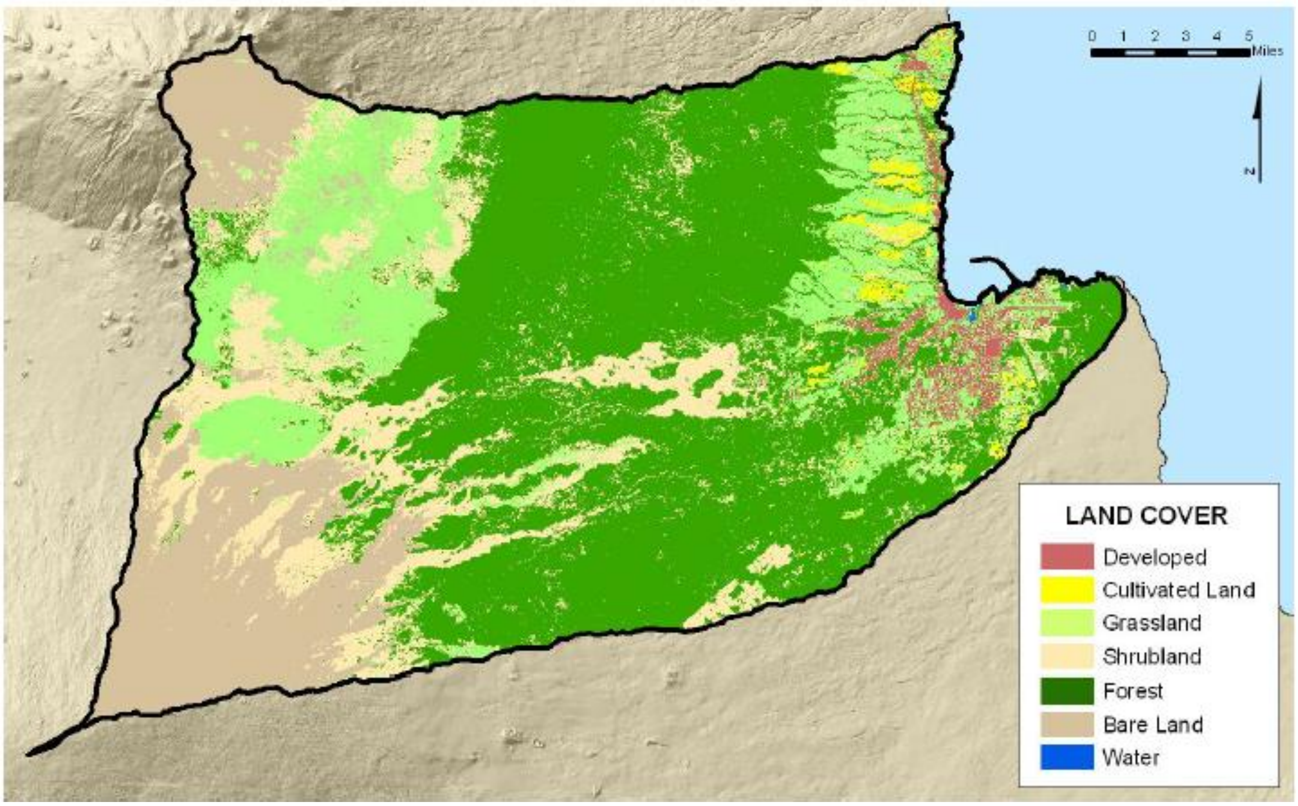


Figure 3. Land cover in the Hilo Bay watershed (USDA NRCS 2009).

B. Balanced Ecosystem Composition. We have defined the Hilo Bay *muliwai* reserve to begin at the headwaters on the summits of the Mauna Kea and Mauna Loa, to extend out into the ocean for a distance of two miles (Fig. 1). The terrestrial area, over 33 km^2, is 70% native-dominated ecological systems (TNC 2008), while the marine component contains representative intertidal, subtidal, and deep habitats, with the aerial cover of any one type not less than 10% of the total area (*see* cover). Being a relatively young coastline, the intertidal area is still in its developing stages of coral reefs, yet a large gradient can be seen from white sandy beaches, black sand beaches, coral heads to coral reefs.

C. Habitat Composition/Complexity.

1. Marine. Along the coastline, there are four types of benthic habitat cover represented. These include coral, macroalgal, turf, and uncolonized (Fig. 4). Of these four, coral cover (10- <50%) represents ~50% of the benthic habitat cover. In Hilo Harbor, Blond Reef and Coconut Island have the highest coral cover, with live coral comprising 1-16% (ACOE 1983). The coral formations are described as varied and relatively stable (as compared to sand and mud) habitat (Sunn et al.1977). Corals found here include: *Montipora verrucosa*, *Pocillopora damicornis*, *Fungia (Pleuractis) scutaria*, *Porites compressa*, *Porites lobata*, *Porites irregularis*, *Montipora patula*, *Montipora flabellate*, *Psammocora (Stephanaria) stellata*, *Leptaastrea pupurea*, *Pavona varians*, and *Cyphastrea ocellina* (Sunn et al.1977). Of these, the one comprising the highest percent cover is *M. verrucosa* (Sunn et al.1977). Coralline algae, *Porolithon*, is abundant and is responsible for consolidating loose reef material and encrusting coral skeletons (ACOE 1983). Uncolonized habitat represents 25% of the benthic habitat cover, while macroalgal and turf represent the remainder. In the rocky intertidal areas, *Ulva*, *Entermomorpha*, *Chaetomorpha*, *Rhodochorto*, *Ahnfeltia concinna*, *Colpomenia*, *Jania*, *Lithothamnion*, *Pterocladia*, *Ralfsia*, *Cladophoropsis*, *Wurdemmania*, *Caulacanthus*, *Gigartina papillata*, *Hildebrandtia*, *Palmella*, *Cruoriella*, and *Corallina* are found (Sunn et al.1977). On coral rubble, *Halimeda*, *Porolithon*, *Codium*, *Amansia*, *Chaetomorpha*, *Dictyota*, *Goniolithon*, *Chondrococcus*, *Cladophora*, *Hemitrema*, *Actinotrichia*, and *Sphacelaria* are found (Sunn et al.1977). Benthic habitat complexity is almost evenly split among rock/boulder, spur/groove, sand, sediment and mud (Fig. 5).

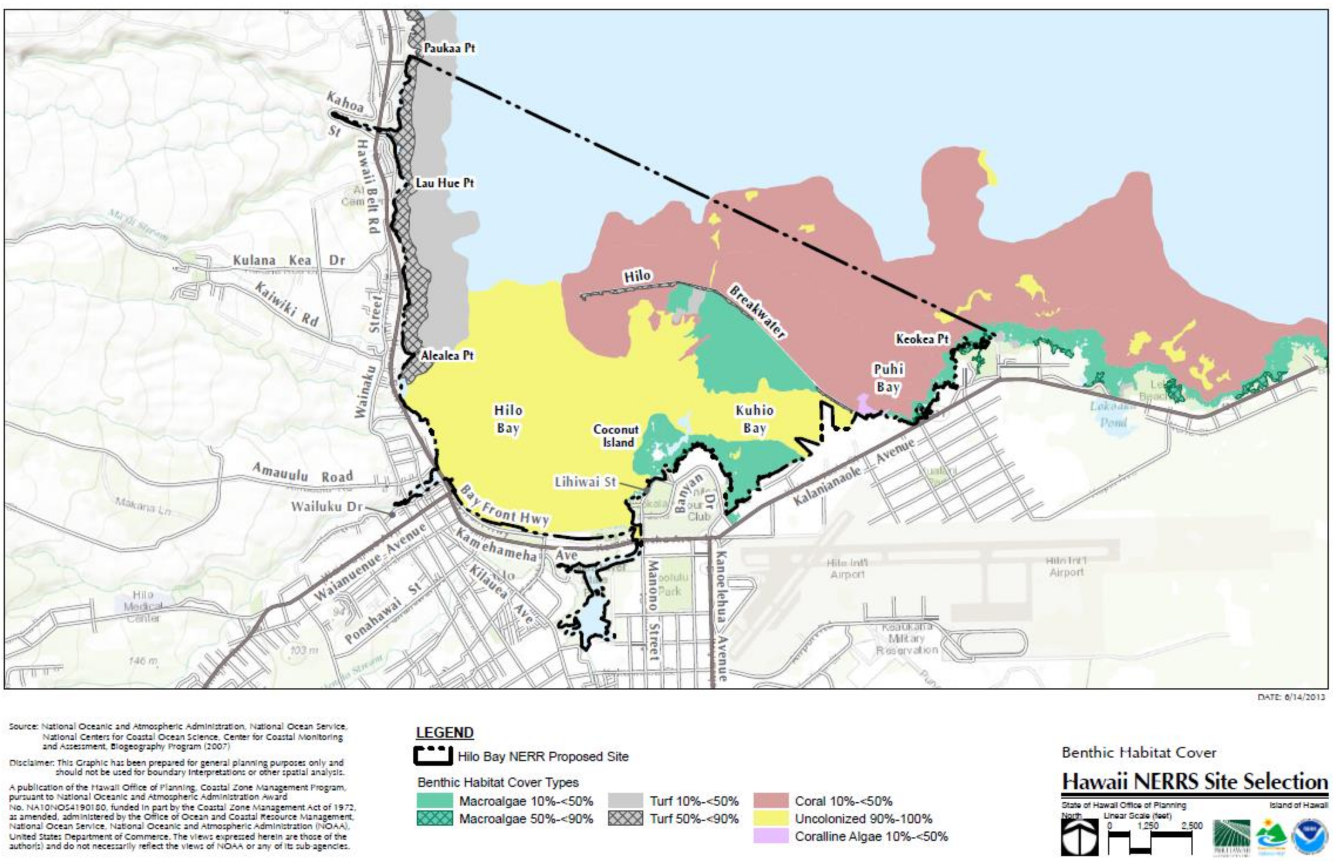


Figure 4. Benthic habitat cover in Hilo Bay *muliwai*.

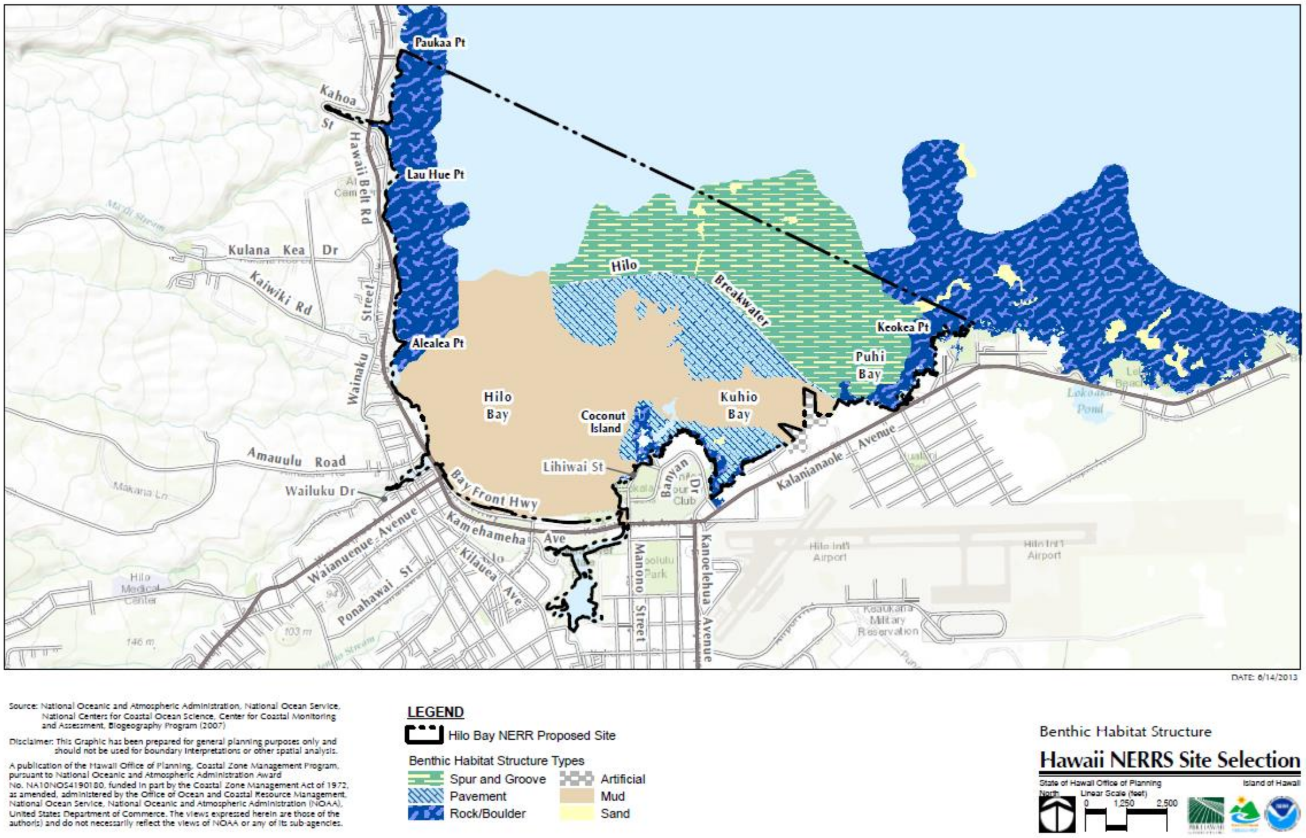


Figure 5. Benthic habitat structure in Hilo Bay *muliwai*.

2. Terrestrial. The *mauka* (towards the mountains) forested lands of the proposed NERRS site include some of the best native contiguous forest in Hawaiʻi and provides important habitat for many species of unique plants and animals. TNC has rated the ecological viability of

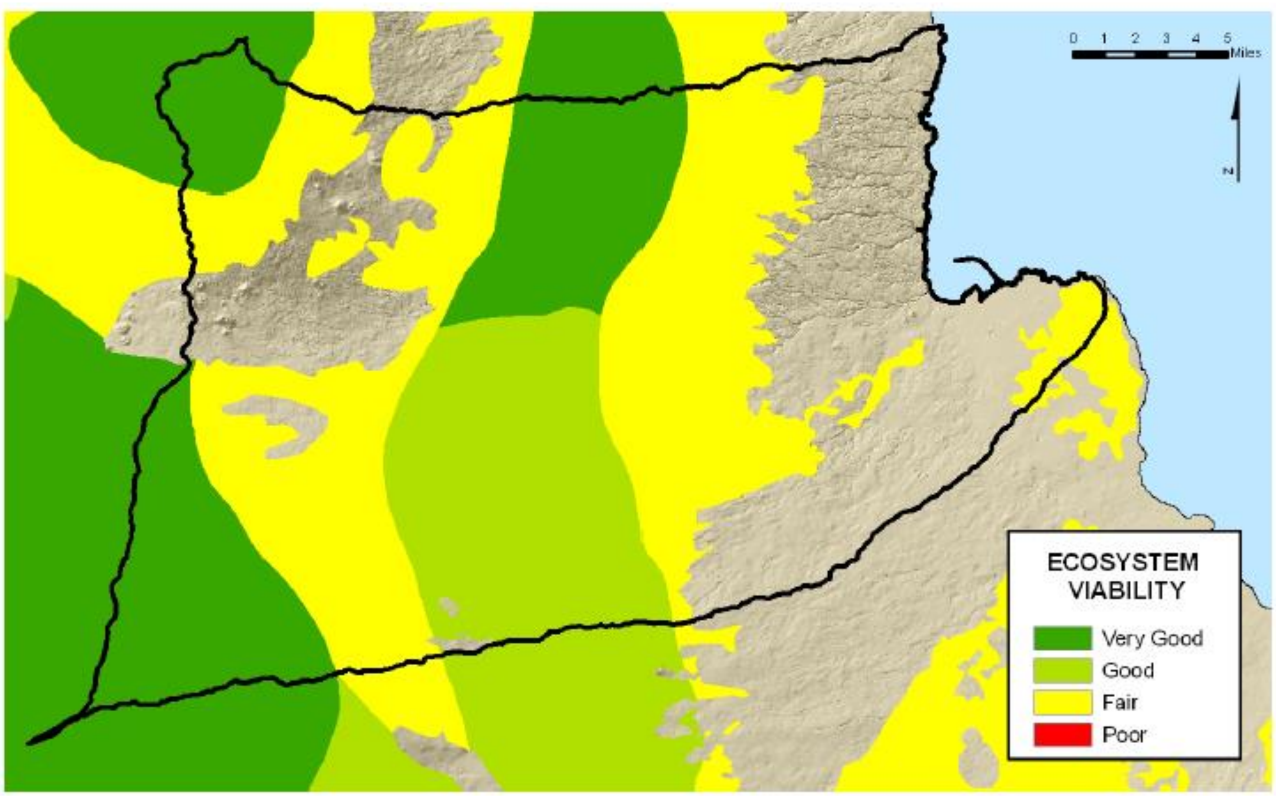


Figure 6. Ecosystem viability in the Hilo Bay watershed (USDA NRCS 2009). Thirty percent of the area is considered to have very good ecosystem viability, 16% good, and 35% fair.

the native-dominated systems using an assessment methodology that considers three criteria: ecosystem size, condition, and landscape context. Analysis of the viability data suggests 30% has very good ecosystem viability, 16% is good, and 35% is fair (Fig. 6). None of the native-dominated land within the Hilo watershed received an assessment rating of poor. Additionally, a large percent of these forest lands have identified by the Department of Land and Natural Resources (DLNR) '*Rain follows the Forest*' initiative (2011) as Watershed Restoration Priority I watersheds for protection (Fig. 7).

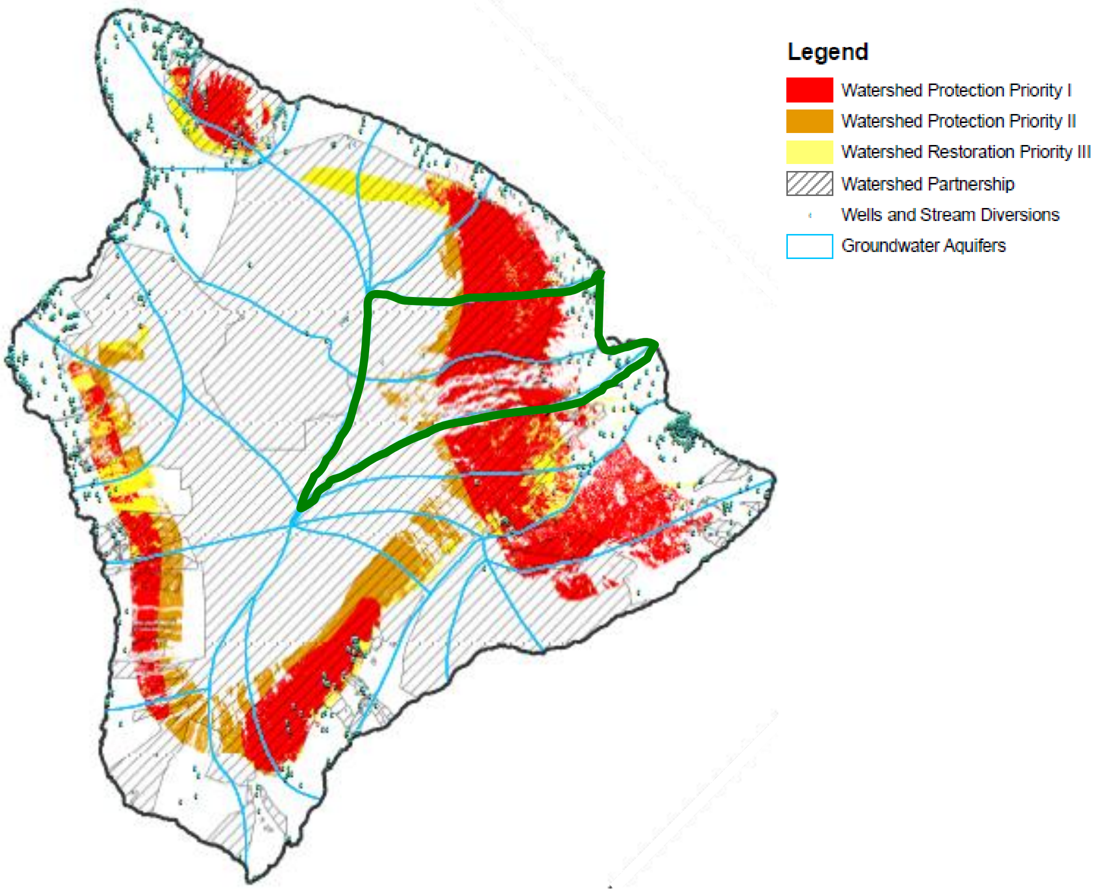
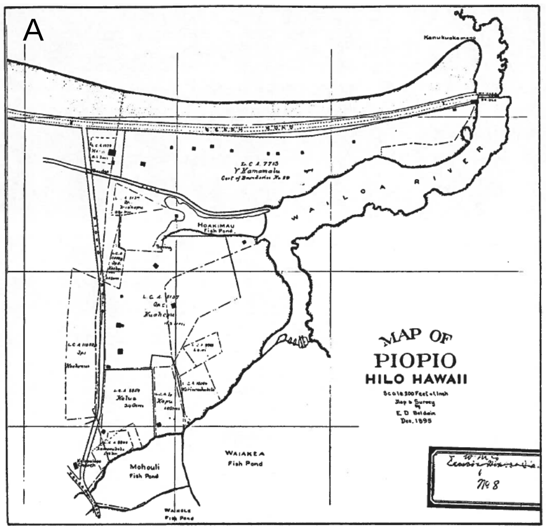


Figure 7. Watershed restoration priority I and II areas within the Hilo Bay watershed according to the Department of Land and Natural Resources, '*Rain follows the Forest*' initiative (2011). Thick green line indicates the Hilo Bay watershed boundary.

D. Habitat Uniqueness of the Site. The fishponds in Waiakea Stream (upper reach of Wailoa River), referred to as the Royal Ponds, were a prime resource of Hilo since early times (Fig. 6A). These spring-fed inland ponds were stocked with fry of striped mullet *('ama 'ama*, *Mugil cephalus*) and milkfish (*awa*) (Fig. 6B). In particular, the *ama 'ama* was a significant species to early Hawaiians; it was coveted by royalty, and there were numerous words in the Hawaiian language describing life stages and migration patterns (Nishimoto et al. 2007). *'Ama 'ama* in four of the fish ponds was reserved for the king's use and remained so for three generations of Kamehamehas (Kelly et al. 1981). During the reign of King Kamehameha I, it was common for some Hawaiian Chiefs to select the swiftest runner to collect the *ama 'ama* from their favorite fishpond so the fish would still be alive when they returned (Fig. 6C). This species is now a more significant recreational fish (Nishimoto et al. 2007) and the current *ama 'ama* fishery in

Waiakea Fish pond is describe in next section of the proposal (*see* E. Significant Faunal and Floral support. Fish and shellfish spawning and nursery grounds.).



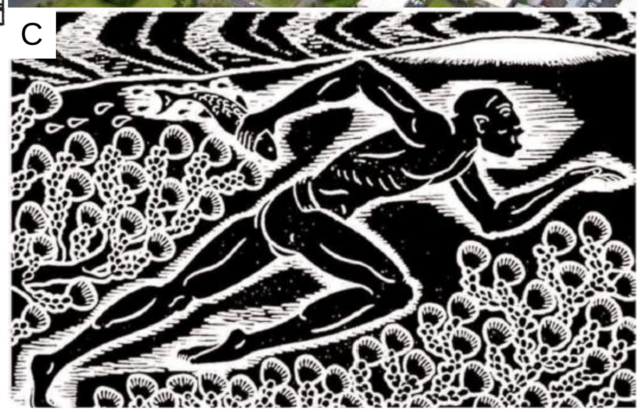


Figure 8. A) Map of `Ili of Pi`Opi`o, the Royal Ponds, where striped mullet (`ama`ama) were cultivated for three generations of Kamehamehas (Kelly et al. 1981). B) Aerial view of Waiakea Fishpond today. C) Makoa and the mullet, print by Dietrich Varez. Note, live mullet in hand being carried from Waiakea Fish Pond in Hilo to the young King Kamehameha in Kawaihae, south Kohala.

Figure 9. Hale o Lono is a traditional fishpond associated with Kalaninuiiamamao, an important chief in the history of Hawai`i island, and it is the only example of a kuapa fishpond on the east side of the island.

The Hale o lono fishpond in Honohononui represents the only kuapa fishpond on the east side of Hawaiʻi Island (Fig. 9). It is culturally significant for its connection to the Hawaiian creation story and Kalaninuiiamamao, an important chief in the history of Island. The Edith Kanaka’ole Foundation currently manages a fishpond on Kamehameha Schools’ property in Keaukaha. This pond is used in their educational programs.

E. Significant Faunal and Floral Support

1. Fish and shellfish spawning and nursery grounds (includes use by either freshwater, estuarine, or estuarine-dependent marine species): Over 72 species of fish have been documented in Hilo Bay muliwai (NIC 1973). The diversity of fishes is similar to the number of species found elsewhere on Hawaiʻi Island. However, the overall abundance is dominated by a few species including: Hawaiian flagtail (*aholehole*, *Kuhlia xenura*), silverside (*ʻiao*, *Atherinomorus insularum*), striped mullet (*ʻamaʻama*, *Mugil cephalus*), convict tang (*manini*, *Acanthurus sandvicensis*), chub (*nenue*, *Kyphosus vaigiensis*), and surgeonfish (*palani*, *Acanthurus dussumieri*). Most of these species are highly prized as game and food fish, or as bait by local fishermen. In recent decades, alien species such as kanda mullet (*Valamugil engeli*) and gold spot sardine (*Herklotsichthys quaddrimaculatus*) have also become prevalent in near-shore habitat around Hilo. Native goatfish (*ʻoama* or *weke*, *Mulloidichthys flavolineatus*) and scad (*halalu* or *akule*, *Selar crumenopthalmus*) also occur in large numbers during summer and fall months. During the *ʻoama* and *halalu* runs each summer, hundreds of these fish are observed in scattered small schools along the shoreline. Other commonly occurring fish include: jacks (*papio* and *ulua*), butterfly fish, goatfish, pomacentrids, milkfish, and cardinal fish.

Hilo Bay serves as juvenile habitat for numerous native and endemic fishes, most of which are also highly prized as game and food fish as adults. These fish include: *ʻama ʻama*, *aholehole*, *ulua* (giant trevally), *weke*, and *akule*. Based on Department of Aquatic Resources (DAR) surveys, juvenile fishes, particularly ʻ*ama ʻama* and *aholehole*, seem to prefer lower salinity waters, which makes Hilo Bay and specific areas within the bay with high freshwater discharge prime habitat for these species. In fact, *aholehole* has been documented using riffles and runs in the terrestrial reaches of Wailoa Stream (McRae et al. 2011).

One species in particular that is especially important in Hilo Bay is the ʻ*ama ʻama*. It is native to Hawaiʻi and lives in the estuary as post-larval recruits, juveniles and adults, usually where there is significant freshwater outflow. In Hilo, there is a specialized hook-and-line recreational fishery targeting ʻ*ama ʻama* where fishers use *Melosira moniliformis*, a chained diatom as bait, which is unique to this region (Nishimoto et al. 2007). Prime area for the ʻ*ama ʻama* fishery in Hilo is located in the Waiakea Public Fishing Area (Nishimoto et al. 2007). It is estimated that the fishery consists of 350 to 400 fishermen. Release and recapture of tagged fish identified Wailoa River and Waiakea Pond as significant nursery habitat for striped mullet. In 1990, the DAR in Hilo opened a hatchery for ʻ*ama ʻama* on the bank of Wailoa River. The release of hatchery fingerlings/year had no negative effect on the native striped mullet stock, but made a significant difference to the fishery (Nishimoto et al. 2007).

Historically, one of the dominant fish found in Hilo Bay was the *nehu* (anchovy, *Encrasicholina purpurea*). The *nehu* was important to the people of old Hawaiʻi, and its occurrence was described in many *mo'olelo*. During the period of commercial fishing in Hilo, *nehu* was used as a bait fish that was caught and used for the *aku* industry. Hilo Harbor was the major baiting grounds for Big Island-based *aku* vessels as it is well protected and has a stratified brackish layer which is conducive to *nehu*. Before World War II, the best baiting grounds were just south of the Wailuku River. Since at least the late 1970's, the *nehu* populations drastically declined (M&E Pacific 1980), have not recovered.

Today, Hilo Bay is more important as a leisure time recreational fishing resource than a seafood source for island residents. The harbor is restricted to commercial fishing except for the collection of bait and pond stock. It is estimated that 2,100 local residents engage in some fishing activity within the Hilo Bay region (Titcomb 1972), the number is probably higher today as Hilo is over 40,000 residents. Shoreline fishermen comprise approximately 60% of fishermen in the Bay, while boat fishermen are concentrated in Waiakea Fish Pond, Wailoa River, and within Hilo Harbor. The areas where fishing pressure for seasonal fish are intense include regions near the tip of the breakwater, the seaward side of the breakwater, Waiakea Fish Pond, Wailoa River, Hilo Bay Front, Radio Bay, and coastal areas along the Keaukaha coastline to the project boundary.

Hilo Bay is a also nursery for both black-tipped reef sharks (*Carcharinus melanopterus*) and the scalloped hammerhead shark (*Sphyrna lewini*). The sandbar shark, *Carcharhinus plumbeus,* is also commonly found in the Bay.

2. Migratory bird and/or waterfowl use: The rivers and fishponds of Hilo once supported great numbers of water fowl, including the endemic Hawaiian duck (*kaloa-maoli*), the coot (*'alae*), and the stilt (*kukuluae'o*), as well as migratory ducks - pintail, widgeon, and shoveler (Kelly et al. 1981). Presently, Hilo Bay is not a major area of concentration for migratory shore- or water birds as a result of removal of natural habitats and predators. However, migratory and domestic ducks are been observed in Waiakea Pond and Division of Forestry and Wildlife has designated portions of Waiakea Pond as migratory fowl refuges. The most common water bird in Waiakea Pond is the domestic mallard (ACOE 1983). The endangered Hawaiian coot has been observed nesting in Waiakea Pond (ACOE 1983) and *nene*, the endangered native Hawaiian goose, are commonly observed in the area.

3. Critical habitat.

a. Marine. Hilo Bay is a critical habitat for juvenile and adult striped mullet 'ama'ama), which is a native species, a popular game/food fish, and a fish that is culturally important to Hawaiians, and was often used in religious ceremonies (Titcomb 1972). Large populations of juvenile and adult striped mullet are present year round in Hilo Bay, making Hilo home to the largest recreational *'ama'ama* fishery in the state.

b. Terrestrial. The Hilo watershed has designated critical habitat for one animal species, *palila* (*Loxioides bailleui*), 12 plant species (*Argyroxiphium kauense, Clermontia lindseyana, Clermontia peleana, Clermontia pyrularia, Cyanea platyphylla, Cyanea shipmanii, Cyanea stictophylla, Cyrtandra giffardii, Cyrtandra tintinnabula, Phyllostegia hawaiiensis, Phyllostegia racemosa, and Phyllostegia velutina*) (USFWS n.d.), and two insect species (*Drosophila mulli and Drosophila ochrobasis*) (Fig. 10). Forest bird recovery habitat, animal/plant sanctuaries, natural areas, forest/game management areas, and parks/recreational areas are delineated on Figure 11. Tse areas include the Hakalau Forest National Wildlife Refuge, Keauhou Cooperative Nene Sanctuary, Kipuka Ainahou Nene Sanctuary, Upper Waiakea Bog Sanctuary, Wailuku Silversword Sanctuary, Mauna Kea Ice Age Natural Area Reserve, and Waiakea 1942 Lava Flow Natural Area Reserve. These wildlife reserves are managed by the DLNR Division of Forestry and Wildlife, with the exception of Hakalau, which is managed by the US Fish and Wildlife Service (USFWS).

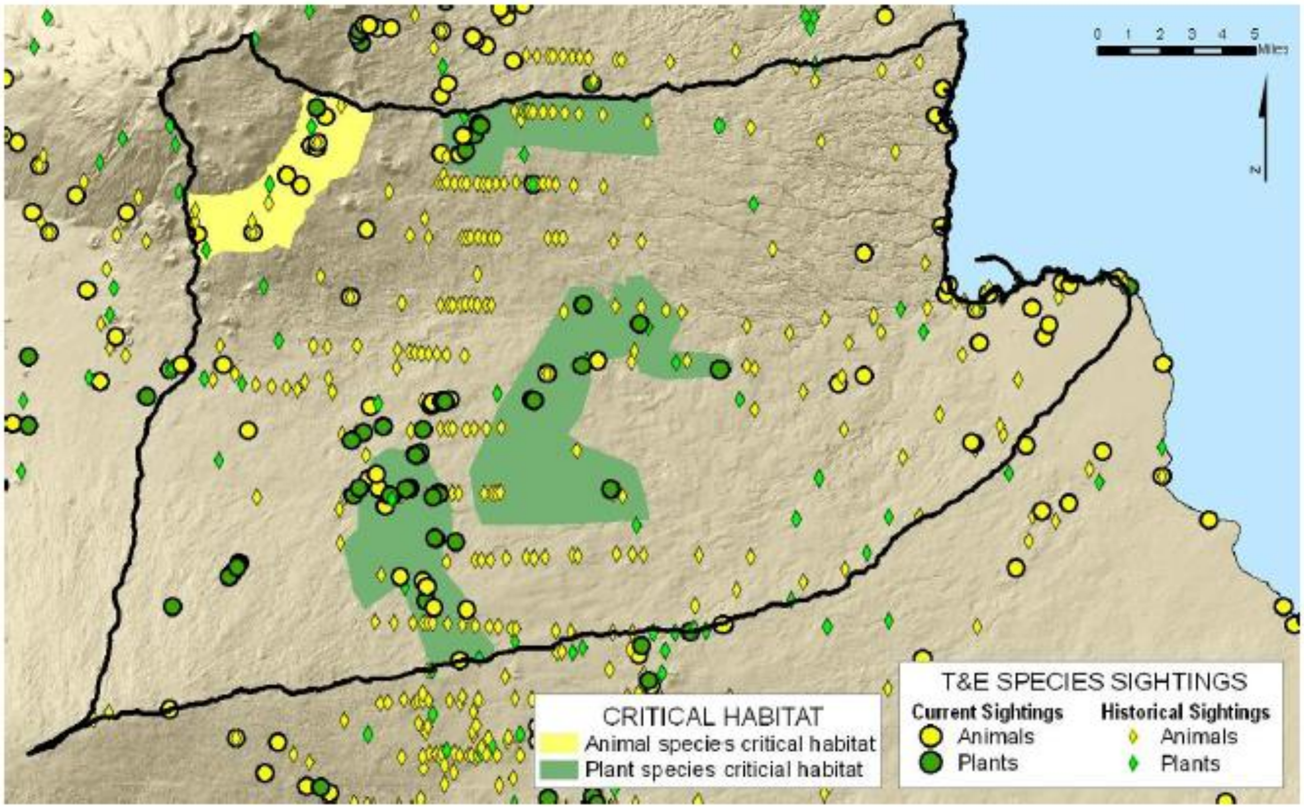


Figure 10. Critical terrestrial habitat for animal and plant species identified in the Hilo Bay watershed (USDA NRCS 2009).

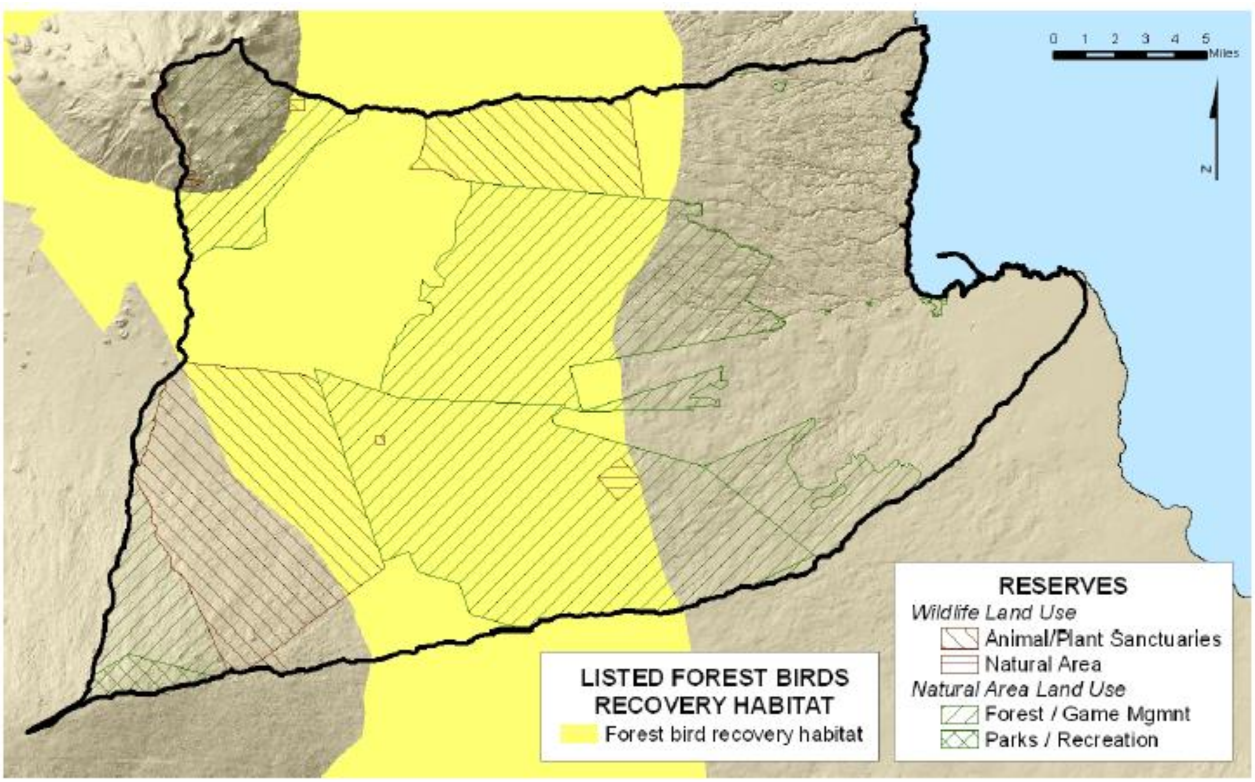


Figure 11. Areas in Hilo Bay watershed that have been set aside for protection of native animals and plants (USDA NRCS 2009).

4. Non-game animals. Over 100 different benthic invertebrate species can be found within Hilo Harbor; there are 27 crustacean species, 21 mollusk species, 14 polychaete worm species, 11 echinoderm species, 10 coral species, 8 tunicate species, and lesser numbers of sponges, bryozoans, and brachiopods. (NIC 1973). In the intertidal zone, snails, mussels, anemones, barnacles, tubeworms, and sponges can be found. The low salinity shoreline areas are encrusted with polychaetes, barnacles, the snails, oysters, and a few encrusting sponges. At the sandy beaches, ghost crabs can be found. In the shallow waters with sandy bottoms comprised of crushed coral and mollusk shells have algae growing on rocks, portunid crabs, and bivalves are common. Diversity of animals in the deep water silt substrate is low and limited to organisms that can tolerate harsh conditions. The only large animals found here are portunid crabs and other small invertebrates such as polychaete tubeworms and nemertin worms.

5. Native species.

a. Marine. In areas with high groundwater discharge around Hilo Bay (Ice Pond, Reed's Bay, Wailoa River, Waiakea Pond), there is a high abundance of *Melosira moniliformis*. This algae is one of the primary food sources for *ʻama ʻama*. Native *ʻaeʻae* (*Bacopa monnieri*) also flourishes in particular areas of Waiakea Pond. Native widgeon grass (*Ruppia maritima*) is also established in some areas of Wailoa River and Waiakea Pond. DAR has conducted a pilot study on native riparian vegetation restoration (*ʻaeʻae*) and its effects on recruitment of native juvenile fishes into the estuary. Their preliminary results show that over 90% of the species composition that utilize the native vegetation for shelter and habitat were native species. Prior removal of riparian vegetation along Waiakea Pond for recreational fishing, made newly recruited mullet fingerlings more vulnerable to piscivorous fish and birds.

b. Freshwater. In the Wailuku River watershed, there are 38 number of native species including crustaceans, fish, snails, worms, and insects (DAR 2008). Four native crustaceans are found and they include: Amphipoda sp., *Ayoida bisulcata*, Copepod sp., and Ostracod sp. Three native fish species are found and they are *Awaous guamensis*, Gobiid sp., and *Sicyopterus stimpsoni*. Two native snail species are found – *Ferrissia sharpi* and *Nertina granosa*. Two native worm species are found –Hirudinean sp. and Oligochaete sp. There are 27 native insect species and they include: *Anax junius*, Anax sp., *Anax strenuous*, *Campsicnemus tibialis*, *Chironomus hawaiiensis*, *Dasyhelea hawaiiensis*, *Forcipomyia hardyi*, Hyposmocoma sp., *Limonia hawaiiensis*, *Limonia jacobus*, *Megalagrion blackburni*, *Megalagrion calliphya*, *Megalagrion hawaiiense*, Megalagrion sp., *Microvelia vagans*, *Paraliancalus metallicus*, Procanace sp., *Rhantus pacificus*, *Saldula exulans*, *Saldula procellaris*, *Scatella clavipes*, *Scatella fluvialis*, *Scatella oahuense*, *Scatella williamsi*, *Sigmatineurum englundi*, Telmatogeton sp., and Tipulid sp. Based on the total watershed and biological ratings, the Wailuku River received a score of 6 (DAR 2008). Most streams in the state had ranks of 5 or less, which is indicative of a lower quality system. The USFWS ranked the Wailuku River as a 'High Quality' stream (1988) and the Hawaiʻi Stream Assessment ranked it a 'Moderately' important for protection (NPS 1990, Fig. 12).

The Wailoa River watershed has fewer native crustaceans, fish, worms, and insects can be found compared to the Wailuku River (DAR 2008). Overall, there were 11 native species identified in the river. There is one native crustacean and one worm, *Macrobrachium grandimanus* and *Myzobdella lugubris*, respectively. There are five native fish and they include: *Awaous guamensis*, *Eleotris sandwicensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis*. There are also five native insects and they include: *Megalagrion* *blackburni*, *Megalagrion calliphya*, *Megalagrion hawaiiense*, and *Megalagrion xanthomelas*. Based on the total watershed and biological ratings, the Wailoa River received a score of 6 (DAR 2008). Most streams in the state had ranks of 5 or less, which is indicative of a lower quality system. The Hawai‘i Stream Assessment ranked the Wailoa River as ‘Substantially’ important for protection (NPS 1990, Fig. 12).

Honoli‘i watershed has 49 native species including crustaceans, fish, snails, worms, and insects. There is one native crustacean - *Atyoida bisulcata*. There are six native fish, including: *Awaous guamensis*, *Eleotris sandwicensis*, Gobiid sp., *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis*. There is one native snail (*Neritina granosa*) and two native worms (*Myzobdella lugubris* and *Amynthas diffringens*). There are 39 native insect species found in Honoli‘i stream and they include: Anax junius, *Anax strenuous*, *Brachydeutera hebes*, *Forcipomyia hardyi*, *Campsicnemus tibialis*, *Chironomus hawaiiensis*, *Dasyhelea hawaiiensis*, Eurynogaster sp., Forcipomyia sp., Hyposmocoma sp., *Limonia hawaiiensis*, *Limonia jacobus*, *Limonia kauaiensis*, *Limonia nigropolita*, Limonia sp., *Limonia stygipennis*, *Limonia swezeyi*, *Megalagrion blackburni*, *Megalagrion calliphya*, *Megalagrion hawaiiense*, Megalagrion sp., *Microvelia vagans*, *Orthocladius grimshawi*, *Procanacae acuminate*, *Procanace confuse*, Procanace sp., *Pseudosmittia paraconjugata*, *Rhantus pacificus*, *Saldula exulans*, *Saldula oahuense*, *Saldula procellaris*, *Scatella cilipes*, *Scatella clavipes*, *Scatella fluvialis*, *Scatella oahuense*, *Scatella warreni*, *Scatella williamsi*, Telmatogeton sp., and *Telmatogeton torrenticola*. Based on the total watershed and biological ratings, the Honoli‘i Stream received a score of 9 (DAR 2008). Most streams in the state had ranks of 5 or less, which is indicative of a lower quality system. Honoli‘i Stream received an ‘Outstanding’ rating from the Hawai‘i Stream Assessment (NPS 1990, Fig. 12) and was recognized as a ‘High Quality’ stream by the USFWS (1988).

Maili Stream watershed has 10 native species including crustaceans, fish, snails, and insects. (DAR 2008). There are three native crustacean, including: *Macrobrachium grandimanus*, *Atyoida bisulata*, and Amphopod sp. There is one native snail – *Neritina ganosa*. There are four native fish and they include: *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and Gobiid sp. There are also two native insects and they include: *Megalagrion sp.* and *Telmatogeton sp.* Based on the total watershed and biological ratings, Maili Stream received a score of 6 (DAR 2008). Most streams in the state had ranks of 5 or less, which is indicative of a lower quality system. The Hawai‘i Stream Assessment ranked Maili Stream as ‘Outstanding’ and considered it worthy for protection (NPS 1990, Fig. 12).

Pukihae Stream watershed has 14 native species including crustaceans, fish, worms, and insects. (DAR 2008). There are four native crustacean, including: *Macrobrachium grandimanus*, *Atyoida bisulata*, Copepod sp., and Ostracod sp. There are two native worms – Hirudinean sp. and *Oligochaete* sp. There are four native fish and they include: *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Gobiid sp.* There are also four native insects and they include: *Megalagrion sp.*, Coleoptera sp., *Telmatogeton sp., and* Tipulid sp. Based on the total watershed and biological ratings, Pukihae Stream received a score of 6 (DAR 2008). Most streams in the state had ranks of 5 or less, which is indicative of a lower quality system. The Hawai‘i Stream Assessment ranked Pukihae Stream as ‘Substantially’ important for protection (NPS 1990, Fig. 12).

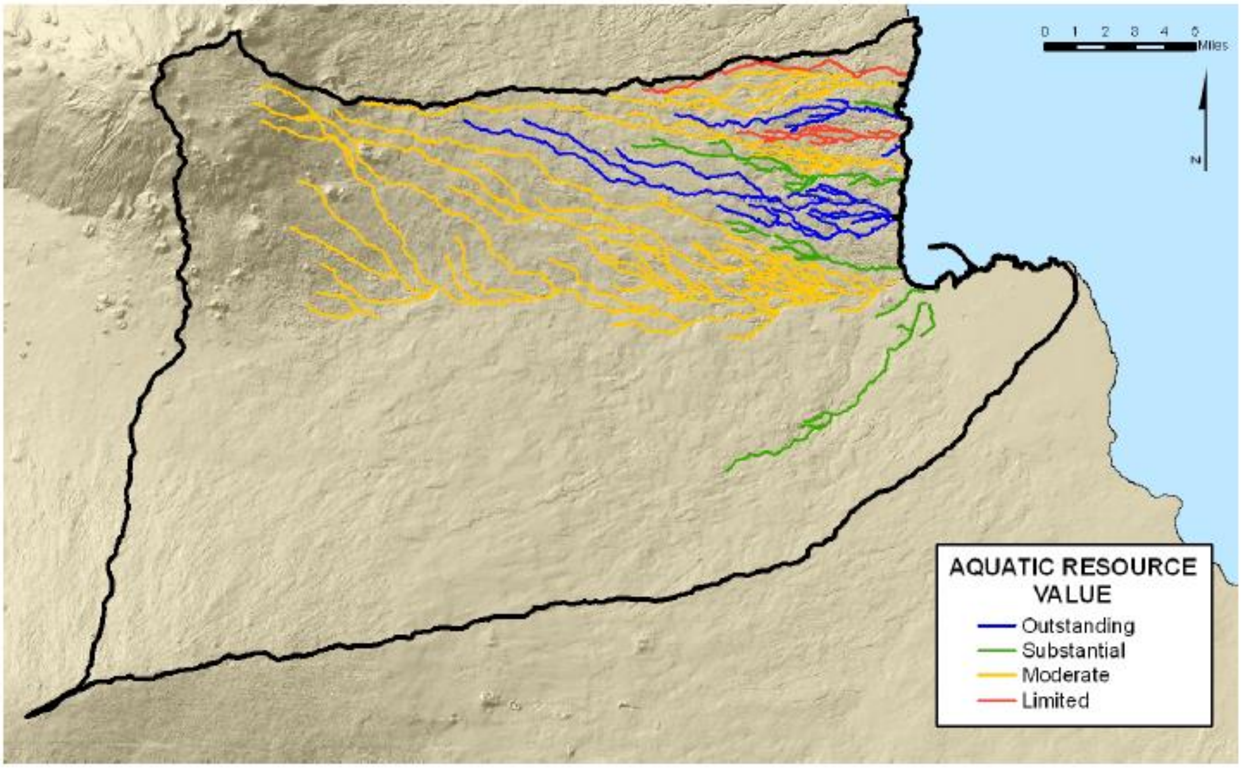


Figure 12. Value of streams according to the Hawai`i Stream Assessment (1990). Rating was based on absence and abundance of indicator native aquatic organisms, evidence of spawning, and alterations to stream conditions. Streams in the Hilo Bay watershed received scores of outstanding, substantial, moderate, and limited (USDA NRCS 2009).

6. Endangered and threatened species. Under the Endangered Species Act, species may be listed as either endangered or threatened. "Endangered" means a species is in danger of extinction throughout all or a significant portion of its range. "Threatened" means a species is likely to become endangered within the foreseeable future. Additionally, the USFWS maintains a list of "candidate" species for which there is sufficient information to warrant a proposed listing, but on which USFWS is precluded from acting due to higher listing priorities (USFWS 2008).

a. Marine and Coastal. There are <u>four endangered or threatened marine species</u> that use Hilo Bay as nursing or feeding grounds. The endangered humpback whale (*kohol*ā, *Megaptera novaeangliae*) seasonally migrates along the Hilo coastline. The whales appear in November and leave by the end of June, with the greatest number between February and March (ACOE 1983). The endangered hawksbill turtle (*honu'ea*, *Eretmochelys imbricata*) and the threatened green sea turtles (*honu*, *Chelonia mydas*) have been observed in Hilo Bay foraging for food. In particular, green sea turtles are found frequently and in high abundance deep within Wailoa River and Waiakea Pond at salinity values < 1 ppt). However, no nesting grounds or seasonal aggregations have been reported for the area (ACOE 1983). The Hawaiian Monk seal (*'īlioholoikauaua*, *Monachus schauinslandi*) swims within the proposed reserve boundaries and has been known to give birth and wean their young at river mouths and coastal areas within the boundaries of the reserve.

b. Freshwater. There are no endangered freshwater species within the proposed site.

c. Terrestrial. Sixteen animal and 24 plant species found within the Hilo watershed are listed as endangered or threatened according to the December 2005 database of the Hawai'i Biodiversity and Mapping Program. Figure 10 identifies distinct point locations where rare animal and plant species have been observed, along with areas where the abundance of observations is too great to show with a single point. Figure 10 also indicates whether the data represents a current or historical sighting, where current is defined as the twenty-year period since 1988. The scientific and common names of the protected species are listed in the following Tables 1 and 2, along with their federal listing status and sighting classification.

Table 1. Threatened and endanger animal species in the Hilo Bay watershed. (USDA NRCS 2009).

T&E Animal Species in the Hilo Watershed

Species Type / ESA Listing Status / **Common Name**	**Scientific Name**	**Species Sightings**	
		Recent	**Pre-1988**
Invertebrates			
Endangered			
Blackburn's Sphinx Moth	*Manduca blackburni*		•
Candidate			
Pacific Megalagrion Damselfly	*Megalagrion pacificum*	unknown	
Orange-black Megalagrion Damselfly	*Megalagrion xanthomelas*	•	
Terrestrial Mammals			
Endangered			
Hawaiian Hoary Bat	*Lasiurus cinereus semotus*	•	•
Birds			
Endangered			
Hawaiian Duck or Koloa	*Anas wyvilliana*	•	•
Hawaiian Goose or Nēnē	*Branta sandvicensis*	•	•
Hawaiian Hawk or 'Io	*Buteo solitarius*	•	•
Hawaiian Crow or 'Alalā	*Corvus hawaiiensis*	extinct in the wild	
Hawaiian Coot or 'Alae Ke'oke'o	*Fulica alai*	•	
'Ākiapōlā'au	*Hemignathus munroi*	•	•
Palila	*Loxioides bailleui*	•	•
Hawai`i 'Akepa	*Loxops coccineus coccineus*	•	•
Hawai`i Creeper	*Oreomystis mana*	•	•
'Ō'ū	*Psittirostra psittacea*		•
Hawaiian Dark-Rumped Petrel or 'Ua'u	*Pterodroma sandwichensis*		•
Threatened			
Newell's Shearwater or 'A'o	*Puffinus auricularis newelli*	•	

In addition to those species listed by the federal and state government as threatened or endangered, the State of Hawai'i has put together Hawai'i's Comprehensive Wildlife Conservation Strategy (CWCS) (Mitchell et al. 2005). The CWCS document identifies "Species of Greatest Conservation Need" for both flora and fauna of Hawai'i. All native animals are considered species of greatest conservation need by the State of Hawai'i, so any native animals found in the Hilo watershed are included. Plants were included using the following criteria: 1) Plant species federally listed as threatened, endangered, or as a candidate for listing; 2) Plant species identified as Plant Extinction Prevention (PEP) plants (i.e., plants with less than 50 individuals extant); 3) Plant species identified as important elements of native habitats; 4) Endemic aquatic plants; and 5) Endemic terrestrial and aquatic algae. A plant species was considered an important element of native habitat if it was a dominant or co-dominant member of an identified natural community as defined by the Manual of the Flowering Plants of Hawai'i, or if there was evidence that the plant was known to act as either a host, a food source, or habitat for native wildlife.

Table 2. Threatened and endangered plant species in Hilo Bay watershed (USDA NRCS 2009).

T&E Plant Species in the Hilo Watershed

ESA Listing Status / Scientific Name	Common Name	Species Sightings	
		Recent	Pre-1988
Endangered			
Adenophorus periens	palai lā‘au		•
Argyroxiphium kauense	Ka‘ū silversword	•	•
Argyroxiphium sandwicense subsp. *sandwicense*	Mauna Kea silversword or ‘āhinahina	•	
Asplenium peruvianum var. *insulare*		•	•
Clermontia lindseyana	‘ōhā wai	•	•
Clermontia peleana subsp. *peleana*	‘ōhā wai	•	•
Clermontia pyrularia	‘ōhā wai		•
Cyanea platyphylla	‘akū‘akū		•
Cyanea shipmanii	hāhā	•	•
Cyrtandra giffardii	ha‘iwale		•
Cyrtandra tintinnabula	ha‘iwale		•
Ischaemum byrone	Hilo ischaemum		•
Phyllostegia racemosa		•	•
Phyllostegia velutina		•	
Plantago hawaiensis	laukahi kuahiwi	•	•
Stenogyne angustifolia			•
Candidate			
Calamagrostis expansa	reedgrass	•	
Christella boydiae			•
Cyanea tritomantha	‘aku‘aku		•
Gardenia remyi	nānū		•
Joinvillea ascendens subsp. *ascendens*	‘ohe	•	•
Microlepia strigosa var. *mauiensis*	palapalai	•	
Phyllostegia floribunda			•
Ranunculus hawaiensis			•

7. Food gathering. Subsistence gathering and fishing has been practiced in Hilo since the arrival of the Polynesian voyagers and continues along the shorelines today. There are three edible seaweed (*limu*) found in Hilo Bay (Kelly et al. 1981). These include: *Enteromorpha prolifera* (*limu‘ele‘ele*), *Grateloupia filicina* (*limu-huluhuluwaena*), and *Ahnfeltiopsis coccina* (*limu-‘aki‘aki*). *Limu-‘ele‘ele* and *limu-huluhuluwaena* grows near-shore in quiet waters on sand, mud, and small rocks. *Limu-‘aki‘aki* has a strong holdfast and requires a strong swimmer and sharp implement to harvest. Limpets (*‘opihi*), sea urchins (*wana*), shrimp (*‘opae*), and crabs (*kuhonu, ‘a‘ama, ‘alamihi*) are also important food sources. Hunting of game birds (pheasant, quail, dove, sandgrouse, chukar, francolin,turkey) and mammals (pigs, sheep, goat, deer) is also prevalent in the Hilo watershed.

F. Salinity/Light/Temperature/Turbidity/Water Motion Gradients: Two of the three estuary types found in Hawai‘i State are located within Hilo Bay (Juvik and Juvik 1998). These include 1) estuaries at the mouth of streams and rivers and 2) locations where streams are absent, but coastal groundwater discharges abundantly near shore.

A range of environmental gradients can be found within the proposed boundaries for the Hilo Bay NERRS site. Within Hilo Bay itself, there are strong temporal and spatial gradients for salinity, temperature, and turbidity as a result of the freshwater inputs from the Wailuku and Wailoa Rivers during dry (baseflow) and storm conditions (Fig. 13). During dry conditions, the

Wailuku and Wailoa Rivers roughly contribute equal amounts of freshwater to Hilo Bay and

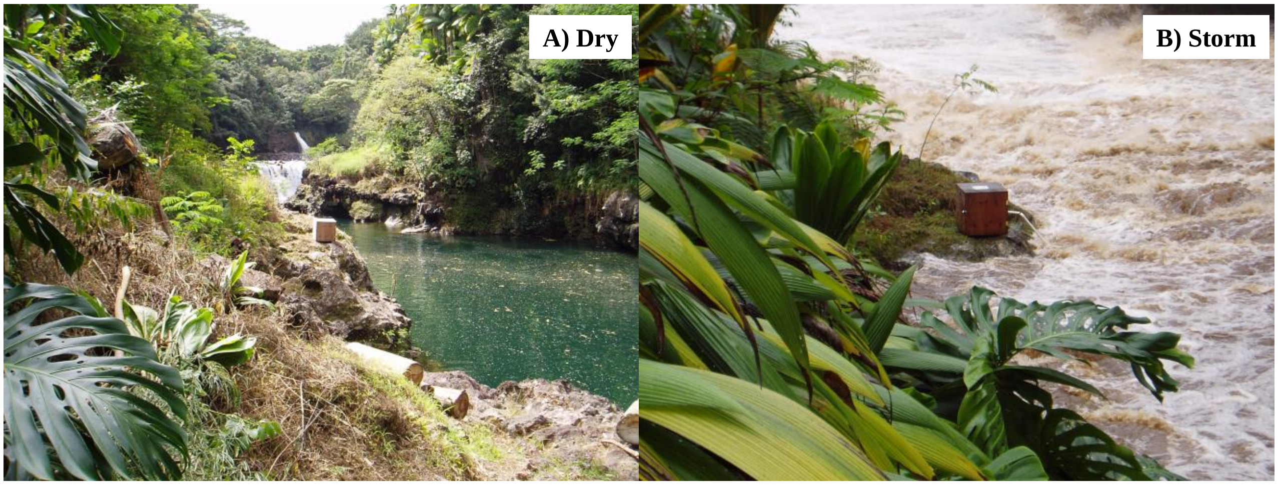


Figure 13. Comparison of A) dry (baseflow) and B) storm conditions for the Wailuku River. The storm sampler was 3 m above the river.

their discharge is primarily from groundwater (Wiegner and Mead 2009). The Wailuku River is mostly perennial from its headwaters to its mouth, but it does have some ephemeral headwater reaches. In contrast, the Wailoa River is ephemeral from its headwaters to the Waiakea Fishpond; here, it is perennial from groundwater discharge. Under dry conditions, water from both rivers are clear, with low turbidity values (range: 0.10 – 1.40 NTU) (Wiegner and Mead 2009). In the steep Wailuku and Honoli'i Rivers freshwater (<1 ppt) is generally found less than 400 m (0.25 mile) from the river mouth. Freshwater pushes further towards the shore during storms and when a sand spit develops at Honoliʻi River. Under dry conditions salinity is generally >3 ppt in the groundwater-fed Wailoa River and Reed's Bay. In Hilo Bay, the surface waters are saltier (range: 16 - 35 ppt), warmer (range: 23 - 26 °C), and clearer (0.10 – 1.38 NTU) (Wiegner and Mead 2009) (Fig. 14). The water column is generally well mixed except at the river mouths where there can be salinity stratification down to 1 m (Fig. 15A,B; Fig. 15). In most areas under dry conditions, light can penetrate to the seafloor (Fig. 15C). Annually, baseflow conditions are present in the Bay approximately 70% of the time (Wiegner et al. 2009). In contrast, storm conditions occur approximately 30% of the time, but can account for 74% of the annual discharge (calculated based on Wailuku River discharge; Wiegner et al. 2009). During storm conditions, the Bay becomes significantly fresher (range: 13.4 – 28 ppt), with cooler surface water temperatures (range: 19.7 – 26.3°C), and higher turbidity values (range: 0.70 - 22.40 NTU) (Fig. 14). Under these conditions, the mouth of the Wailuku River becomes a salt-wedge estuary (Fig. 15A). The freshwater layer can extend down to 3 m below the surface (Fig. 14A). Light attenuation is rapid under these conditions not only in front of the Wailuku River mouth, but outside the breakwall as well (Fig. 15C).

Water motion within Hilo Bay varies both spatially and temporally. The flow found in each river is reflected in their names: Wailuku River, meaning water of destruction, and Wailoa River, meaning broad river. The Wailuku River is relatively steep, with a gradient greater than 2% in the lower reaches, with relatively swift moving water. The Wailuku River has an annual average discharge of approximately 5 m^3/s. But, storm events can generate peak flow 1-3 orders of magnitude greater, equivalent to average flows of the Colorado River through the Grand Canyon (Fig. 12). In Hawai'i, 25% of all river drownings have occurred in the Wailuku River. The Wailoa River, on the other hand, has a gradient of about 0.2%, spreading out into a

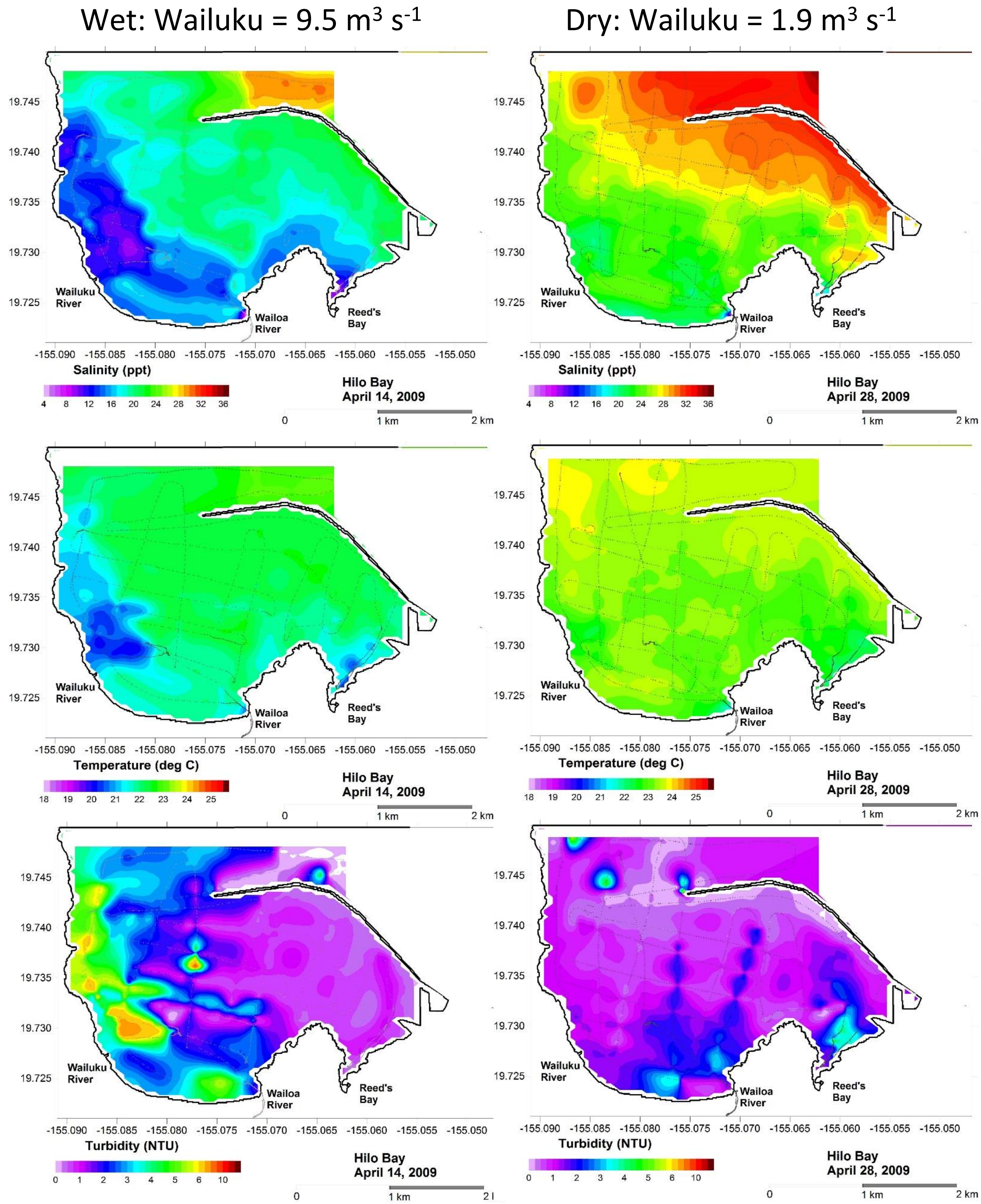


Figure 14. Comparison of spatial distributions for surface water salinity, temperature, and turbidity for Hilo Bay during wet and dry conditions (Adolf et al. unpublished data). Discharge at the top of each column is prior 3-day average.

series of shallow (< 1.8 m), tidally-influences, brackish ponds before flowing out into the Bay (Fig. 8). Reeds Bay is unique as a salt-wedge estuary formed entirely by groundwater inputs (Fig. 16A). Honoli'i Stream similarly has a steep gradient of about 2% in the lower reaches (Fig. 16B). At the shoreline, an ephemeral sand spit extends northward from the shoreline and waxes or wanes, depending on wave conditions. The sand spit creates a broad pool of fresh water and prevents seawater from flowing up into the estuary.

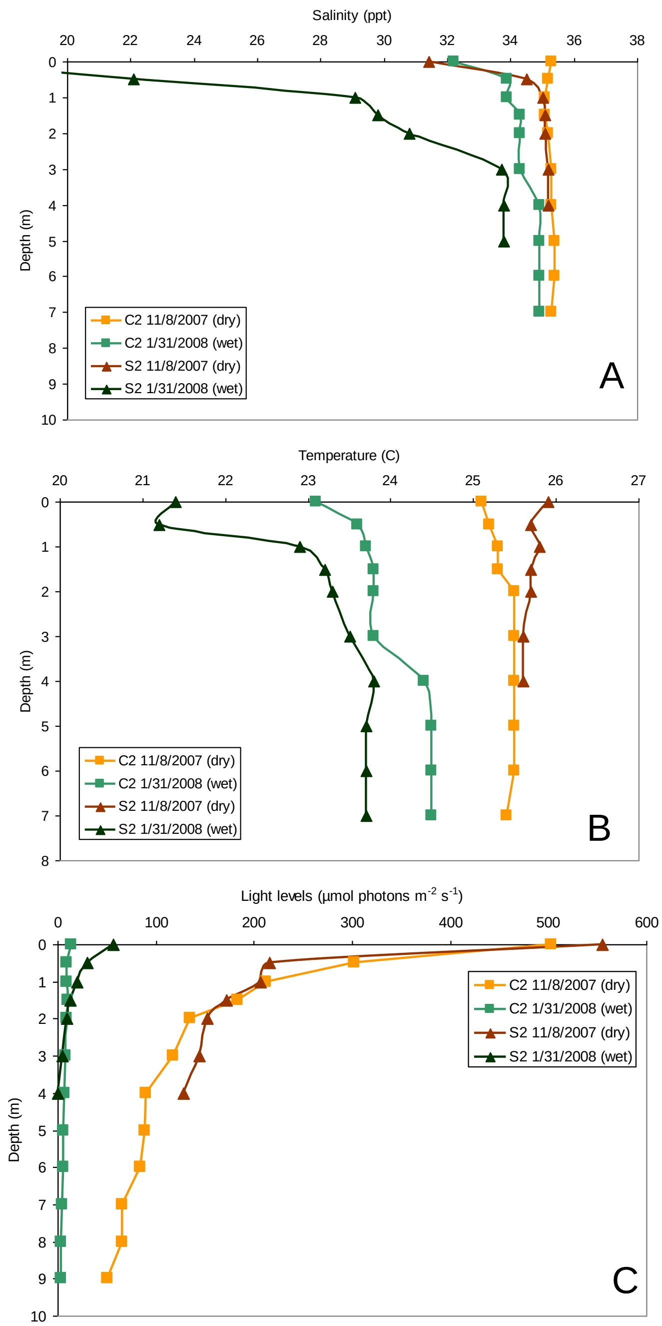


Figure 15. A) Salinity, B) temperature, and C) light attenuation profiles for two stations in Hilo Bay during dry and wet conditions. Station C2 is located outside the breakwater and outside the direct influence of the two rivers. Station S2 is located at the mouth of the Wailuku River in front of the singing bridge.

All this freshwater discharging into Hilo Bay impacts surface current direction and speed. In the outer part of the Bay, groundwater inputs from the Harbor and Reeds Bay, along with persistent northeast trade winds, generate a surface current that generally flow towards the west at 5 cm/s and out of Hilo Bay (M&E Pacific 1980; ACOE 2009). Stratification and circulation in the Bay change in response to storms. For example, mass balance estimates (M&E Pacific 1980) of the residence time of Hilo Harbor during the dry season was 3.5 days, and 2.5 days during the wet season. Storms, however, decreased residence time to 1.3 days, reflecting significant increases in outflowing current speeds associated with these river plumes exiting the bay. Outside the bay, the regional North Hawaiian Ridge Current generally flows towards the northwest, but may vary due to the presence of large-scale eddies (Laevastu et al. 1964; Carson et al. 2013).

Below the 1-3 m deep brackish surface layer, deep water flows into Hilo Harbor. The mouth of Hilo Harbor averages 16.5 m (55 ft) deep, deep enough for the occasional humpback whale to come inside the breakwater. The northern part of the Harbor is dredged to 11 m (25 ft) for commercial shipping. The deep water flowing into the Bay has similar physical and chemical characteristics to surface water found further offshore, and eventually mixes upward to become part of the brackish surface flow.

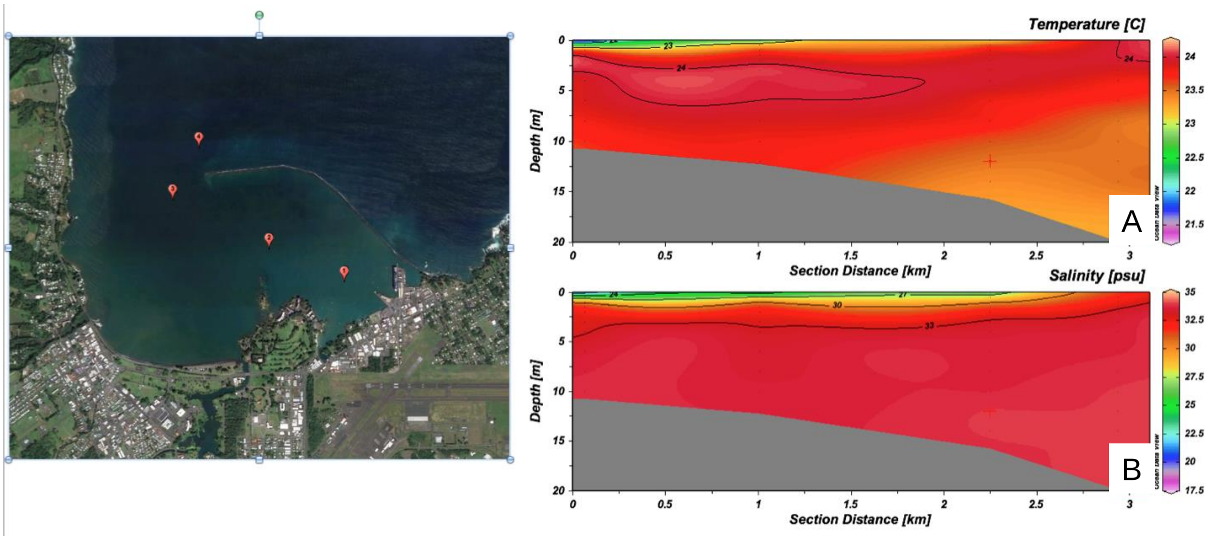


Figure 16. Typical cross-section of A) temperature and B) salinity in Hilo Bay, March 10 2010.

Water motion driven by waves varies considerably throughout the site. The shoreline near Honoli'i Stream is the prime surf spot for Hilo because of its reliable waves generated by the northeast trade winds (Fig. 17C). Near the Wailuku River and Puhi Bay, the shoreline is sheltered from all directions except the north, the primary direction of winter waves generated by north Pacific storms. Towards the east, wave activity decreases moving behind the breakwater. At the far end of the harbor, Reed's Bay is nearly completely sheltered from wave activity.

Figure 17. A) Reeds Bay – a groundwater-fed salt-wedge estuary. B) Honoli`i Stream has a steep gradient and its river mouth and its cove is a favorite local surf spot (C) where the Hawaiian Monk seal can sometimes be found sunning themselves (D).

G. Degree Developed and Potential Impacts to Water Quality: Surface water inputs to Hilo Bay are dominated by two rivers, the Wailuku River watershed to the north, and the Wailoa River watershed to the south. The Wailuku River watershed is the largest watershed in the state, encompassing 653.2 km^2 with headwaters starting near 4,200 m in elevation on the slopes of Mauna Kea (Table 3). The Wailoa River watershed encompasses 255.4 km^2 with headwaters starting near 2964 m in elevation on the slopes of Mauna Loa (Table 3). Both the Wailuku and Wailoa Rivers' watersheds are dominated by evergreen forest (50%), much of which is native vegetation above 2,500 m and within the conservation land use category (over 70%) (Table 3). Hawai‘i State is the largest landowner in both watersheds and the Mauna Kea Watershed Alliance and Three Mountain Alliance help manage and protect these lands along with DLNR. There are also three other watersheds that discharge into the proposed boundary of the Hilo Bay *muliwai* and they include Honoli‘i Stream, Maili Stream, and Pukihae Stream (Table 3).

Table 3. Characteristics of the Wailuku, Wailoa, Honoli‘i, Maili, and Pukihae watersheds. Information from Hawai‘i DAR Watershed Atlas (2008).

Parameter	Wailuku	Wailoa	Honoli‘i	Maili	Pukiihae
Watershed area (km^2)	653.2	255.4	39.2	10.1	7.9
Headwater elevation (m)	4200	2964	1867	865	711
%High-intensity developed	0.1	1.2	0.2	0.5	0.5
Low-intensity developed	0.2	2.7	0.4	0.7	0.3
Cultivated land	0.2	0.5	4.6	4.6	6.3
Grassland	20.6	7.8	10.3	27.0	32.8
Evergreen forest	31.8	67.7	77.3	57.5	52.3
Scrub/shrub	18.1	14.6	7.2	9.3	7.7
Bare land	28.9	5.3	0.0	0.2	0.0
Emergent wetland	0.0	0.0	0.0	0.0	0.0
Water	0.0	0.1	0.0	0.0	0.0

Several segments of coastal and inland waters in the Hilo Bay watershed have been on the Hawai‘i State Department of Health (HDOH) 303d list of impaired waters for several years, and Bay waters have been known to exceed state water quality standards since the 1970s (Silvius et al. 2005). Three rivers draining into Hilo Bay are listed for exceeding HDOH standards (Table 4). These rivers include: Wailuku, Wailoa, and Honoli‘i. Listings for these rivers are based on visual assessments, not on numeric ones (HDOH 2004). All three rivers are listed for high levels of nutrients, but Honoli‘i is also listed for high levels of turbidity (Table 4). Sampling from Wailuku and Wailoa Rivers from 2007 to 2008 under both dry and wet conditions indicate that the Wailoa River substantially exceed the total dissolved nitrogen (TDN, Fig. 18) and NO_3^-+NO_2- (Fig. 19) under both dry and wet conditions, while the Wailuku River only slightly exceeded the NO_3^-+NO_2- standard during dry conditions (Wiegner and Mead 2009). Differences in nitrogen concentrations between the two rivers most likely results from land use differences between the two watersheds. Approximately, 4% of the Wailoa River's drainage is comprised of low- and high-intensity development and agriculture as compared to 0.5% for the Wailuku River's watershed (Table 4). No data were collected from Honoli‘i River during this study.

Table 4. Freshwater segments in the Hilo Bay watershed that are listed as impaired according HDOH (2004). TMDL priority: L= low, M = medium, H = high.

Listed stream	Pollutant(s)	Basis for listing	Station ID	Standard	TMDL priority
Wailuku	NO_3^- $+NO_2$-	Visual assessment	8-2-60		L
Waiakea Stream (Wailoa River tributary)	Nutrients	Visual assessment	8-2-61		TMDL in process
Wailoa River	Nutrients Turbidity	Visual assessment	8-2-61		M
Honoli‘i Stream	Nutrients Turbidity	Visual assessment	8-2-56	Dry	M

Several areas around the perimeter of Hilo Bay have also been listed as impaired by HDOH (Table 5). These areas are listed for high nutrients, turbidity, and *Enterococcus*, a fecal indicator bacteria. From 2007 to 2008, Hilo Bay was sampled for water quality at six stations. Three of the four stations sampled within Hilo Bay had TDN concentrations below HDOH's dry condition standards for embayments (Fig. 20). In contrast, concentrations in front of the Wailoa River mouth exceed HDOH's dry condition standards for embayments five of the eight days sampled (Fig. 20). TDN concentrations outside the breakwater were below HDOH's standard for open coastal waters (Fig. 20). On all sampling dates for this study, $NO_3^-$$+NO_2$- concentrations at one or more stations inside Hilo Bay were above the HDOH's standards for embayments, with the highest concentration being ~46 times higher than the HDOH standard (Fig. 21). $NO_3^-$$+NO_2$- concentrations outside the breakwater exceed open coastal water standard about half of the time (Fig. 21). Turbidity levels within the bay and outside the breakwater were below the HDOH standards during dry conditions (Fig. 22). Chlorophyll *a* (Chl *a*) concentrations inside Hilo Bay were above the HDOH's standard for embayments at all of the stations two to six of the eight sampling dates, with the highest concentration measured being 15.5 times higher than the HDOH standard (Fig. 23). Enterococci levels only exceeded HDOH standards during storms (Fig. 24); their concentrations were also significantly related to turbidity and total suspended solids (TSS) levels suggesting their source is from soils, not sewage (Fig. 25). Previous studies from Hawaii and other tropical areas have shown that Enterococci can be found in soils and that high concentrations in these regions are not necessarily indicative of sewage (Hardina and Fujioka 1991; Fujioka et al. 1999).

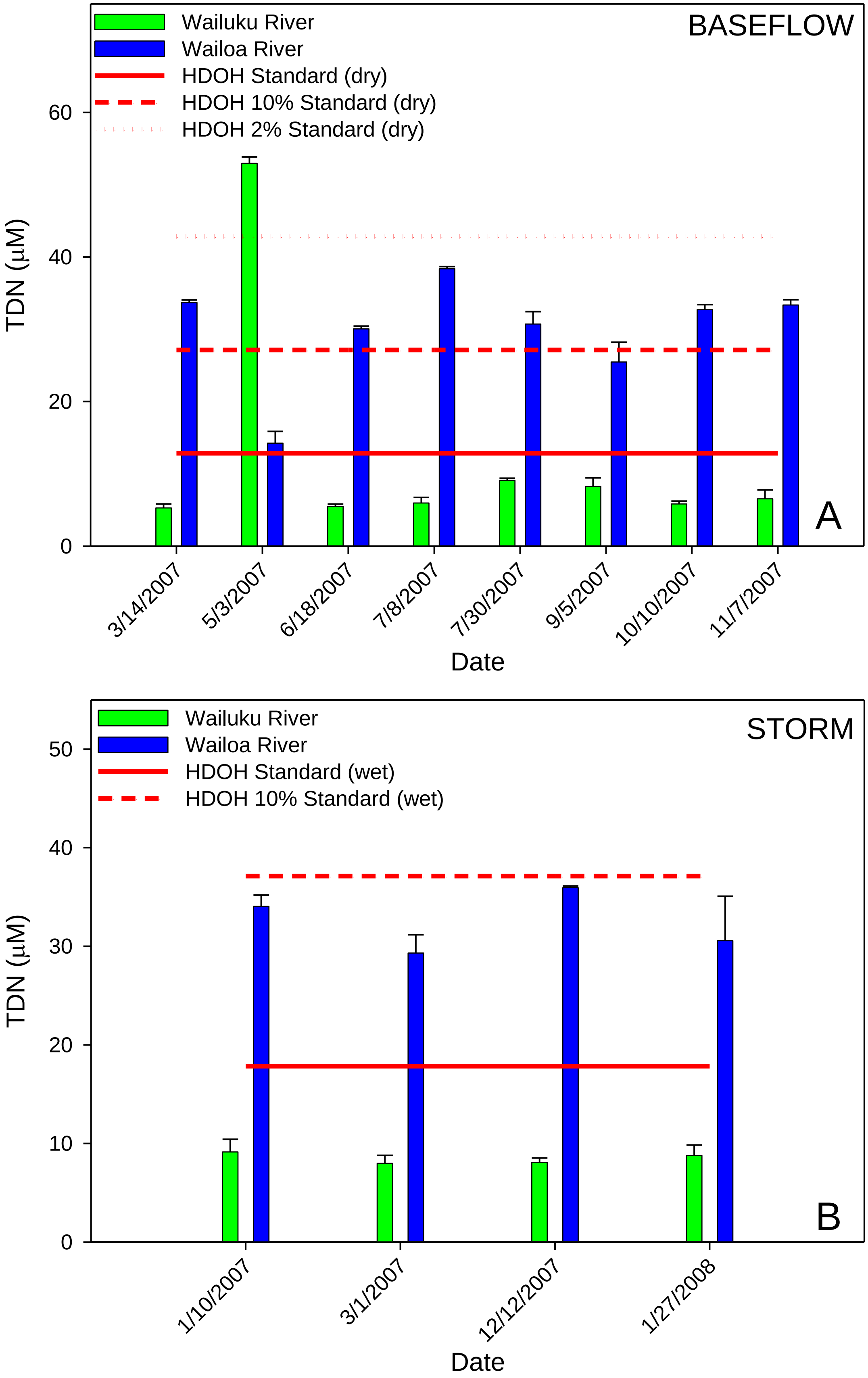


Figure 18. Average (±SE) TDN concentrations in the Wailuku River and Wailoa Rivers during A) baseflow and B) storm conditions (Wiegner and Mead 2009).

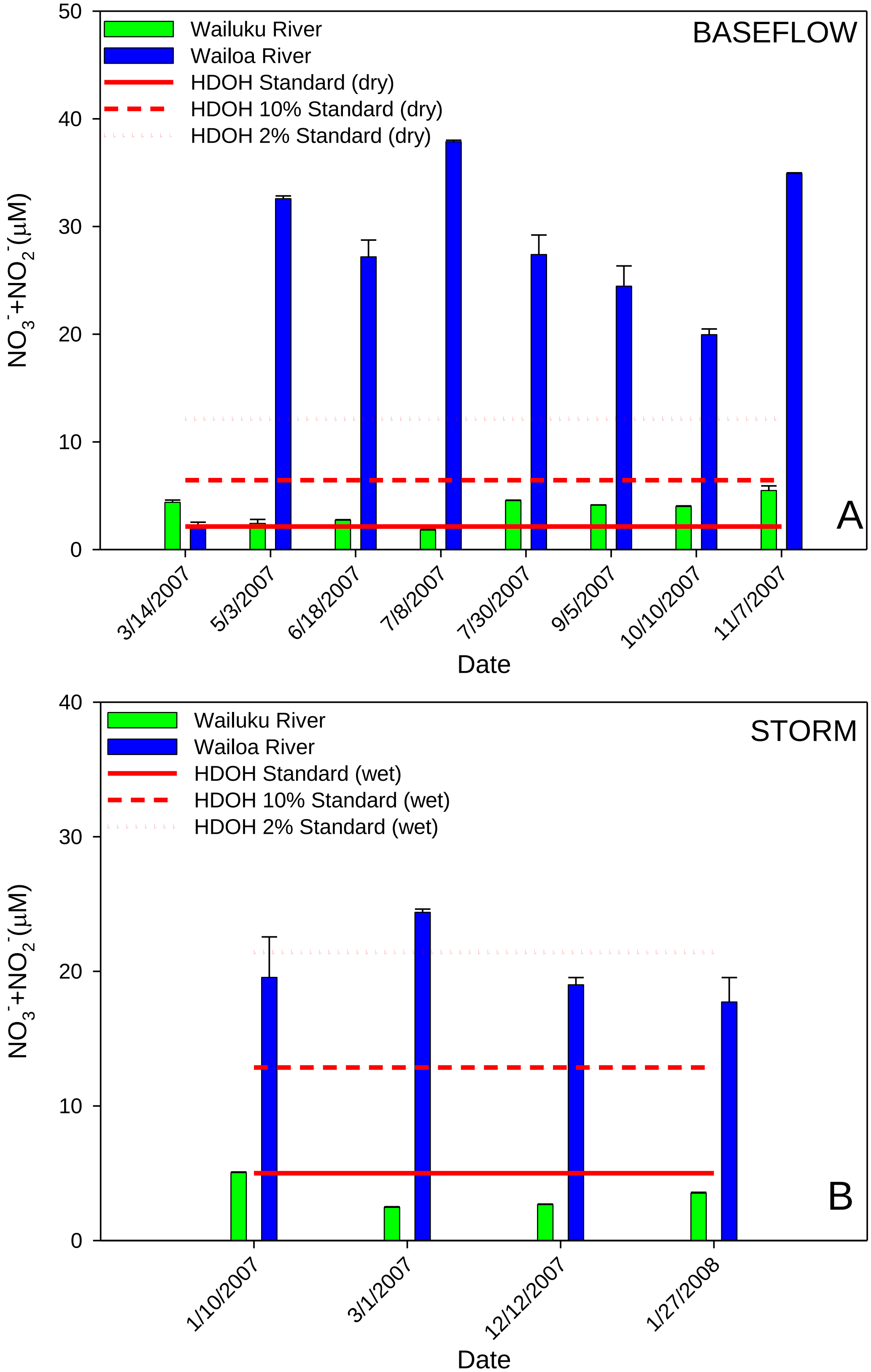


Figure 19. Average (±SE) $NO_3^-+NO_2^-$ concentrations in the Wailuku and Wailoa Rivers during A) baseflow and B) storm conditions (Wiegner and Mead 2009).

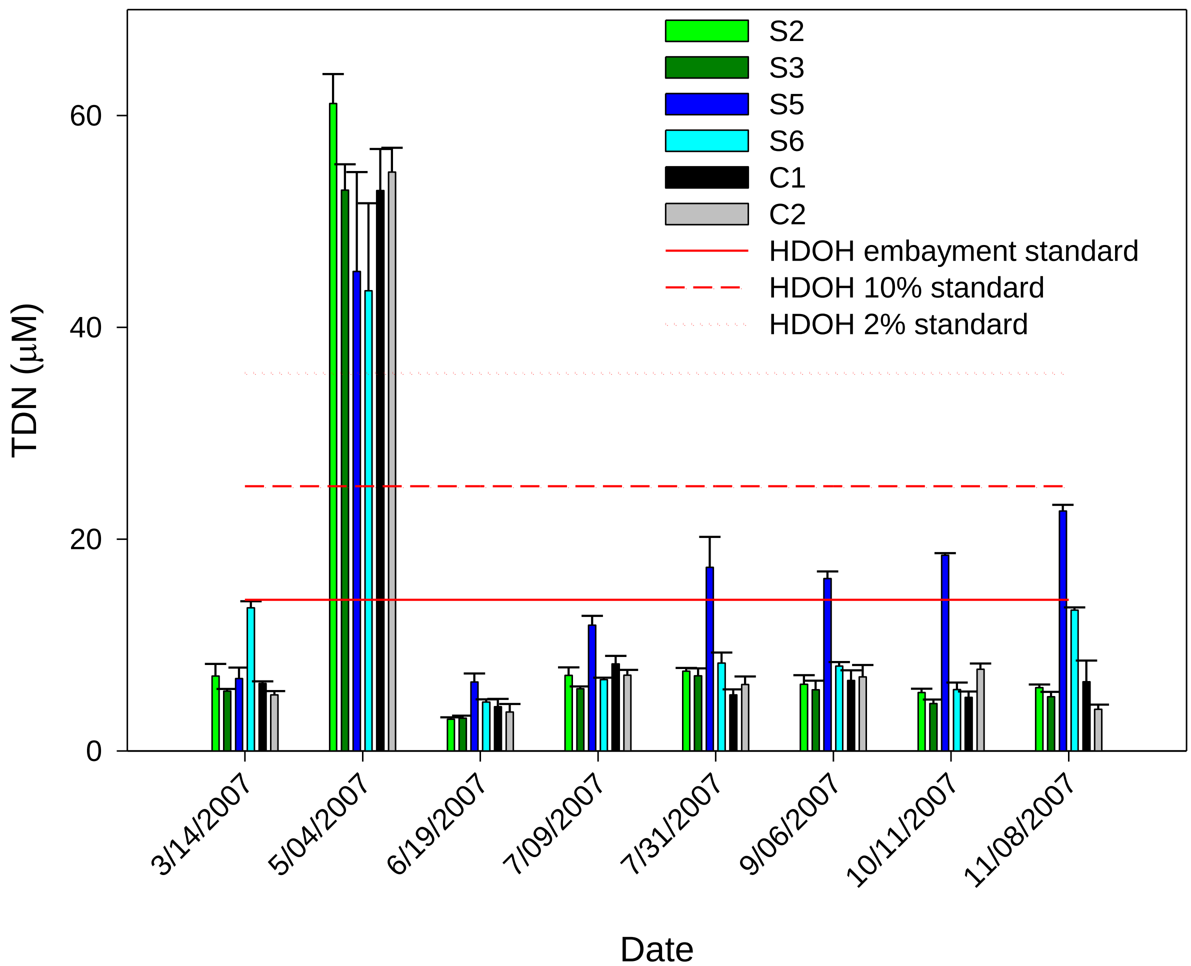


Figure 20. Average (±SE) TDN concentrations during baseflow conditions in Hilo Bay. Stations S2 and S3 are located at the mouth Of the Wailuku River, S5 and S6 are located at the mouth of the Wailoa River, and C1 and C2 are located outside of the breakwall (Wiegner and Mead 2009).

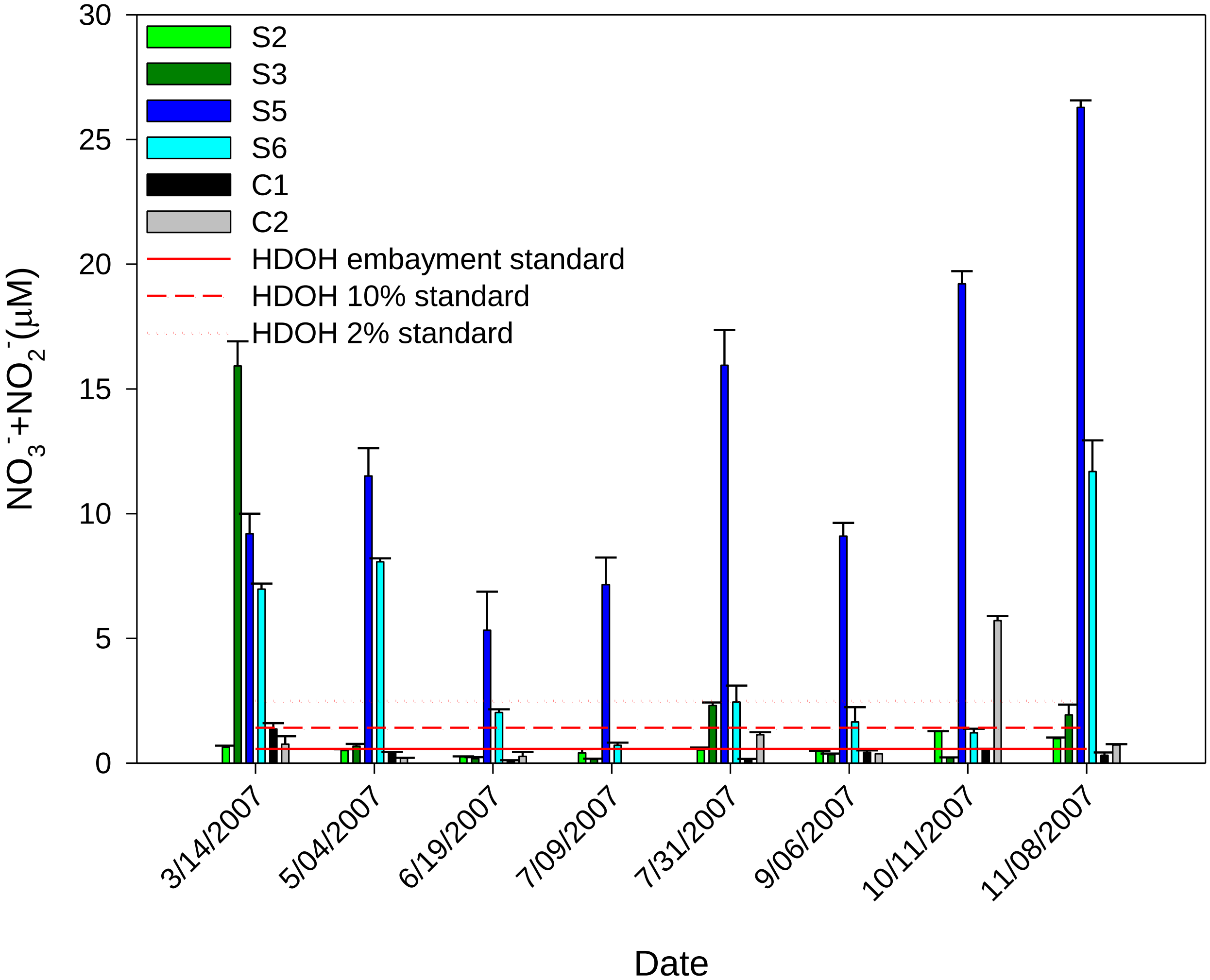


Figure 21. Average (±SE) NO_3^- +NO_2^- concentrations during baseflow conditions in Hilo Bay. Stations S2 and S3 are located at the mouth Of the Wailuku River, S5 and S6 are located at the mouth of the Wailoa River, and C1 and C2 are located outside of the breakwall (Wiegner and Mead 2009).

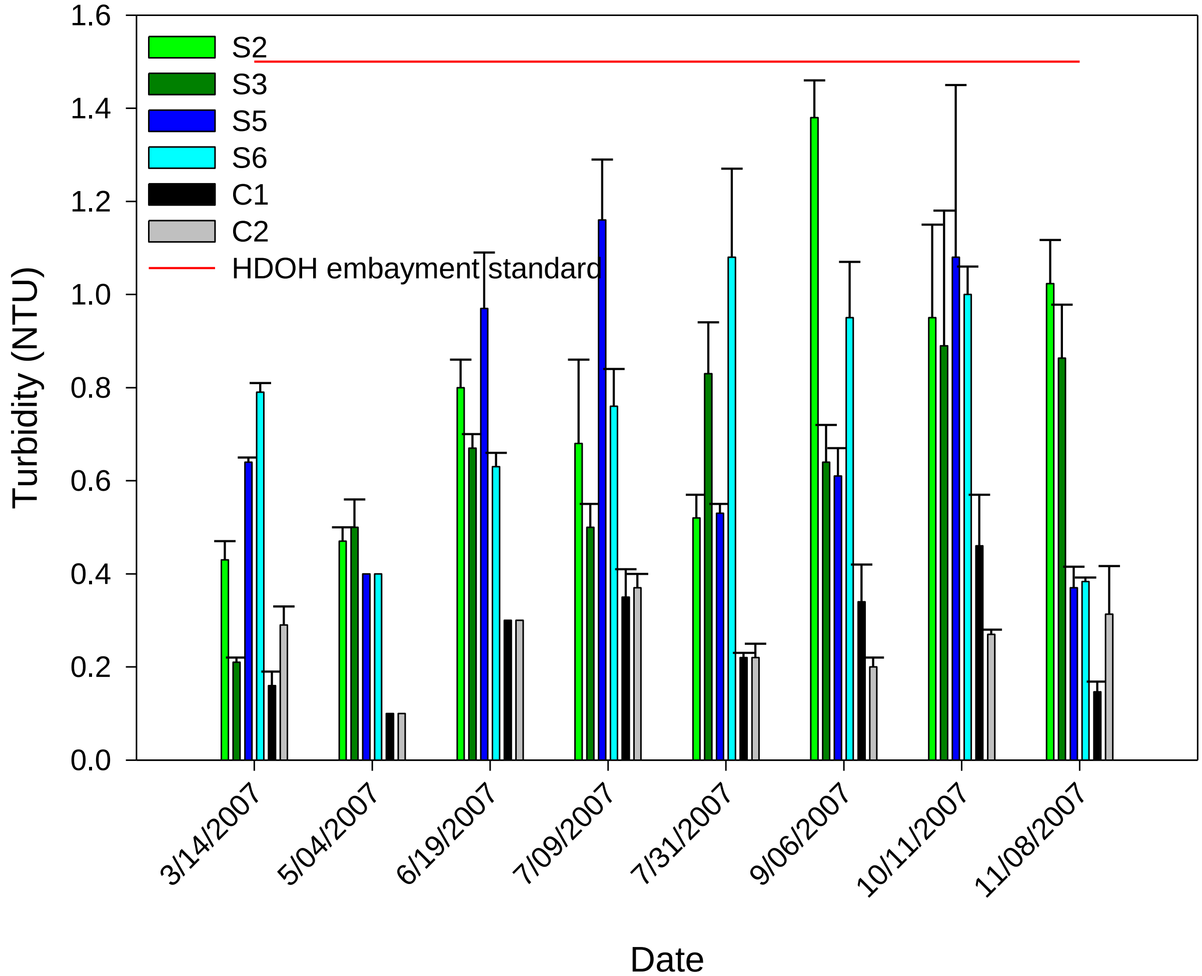


Figure 22. Average (±SE) turbidity concentrations during baseflow conditions in Hilo Bay. Stations S2 and S3 are located at the mouth Of the Wailuku River, S5 and S6 are located at the mouth of the Wailoa River, and C1 and C2 are located outside of the breakwall (Wiegner and Mead 2009).

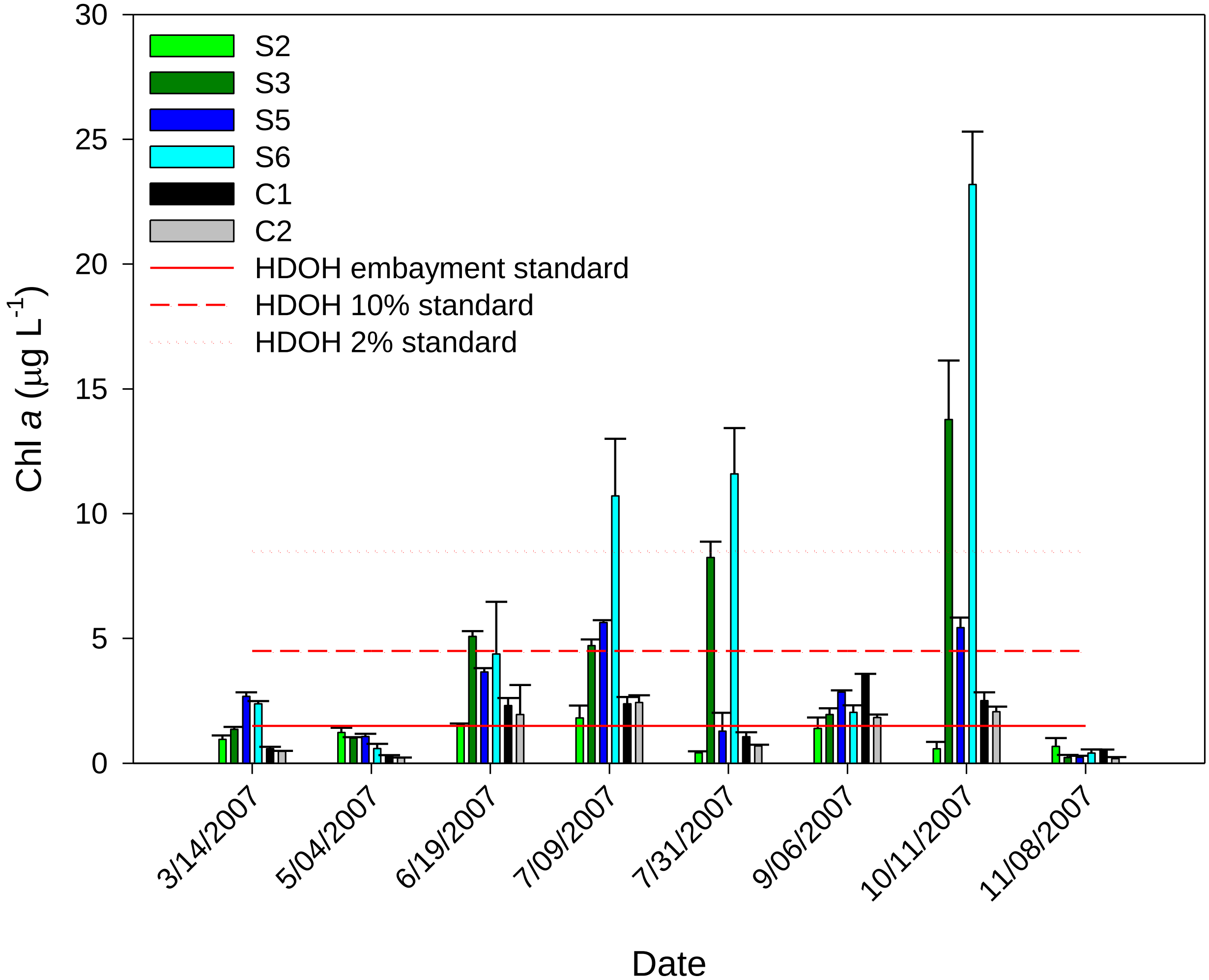


Figure 23. Average (±SE) chlorophyll *a* (Chl *a*) concentrations during baseflow conditions in Hilo Bay. Stations S2 and S3 are located at the mouth Of the Wailuku River, S5 and S6 are located at the mouth of the Wailoa River, and C1 and C2 are located outside of the breakwall (Wiegner and Mead 2009).

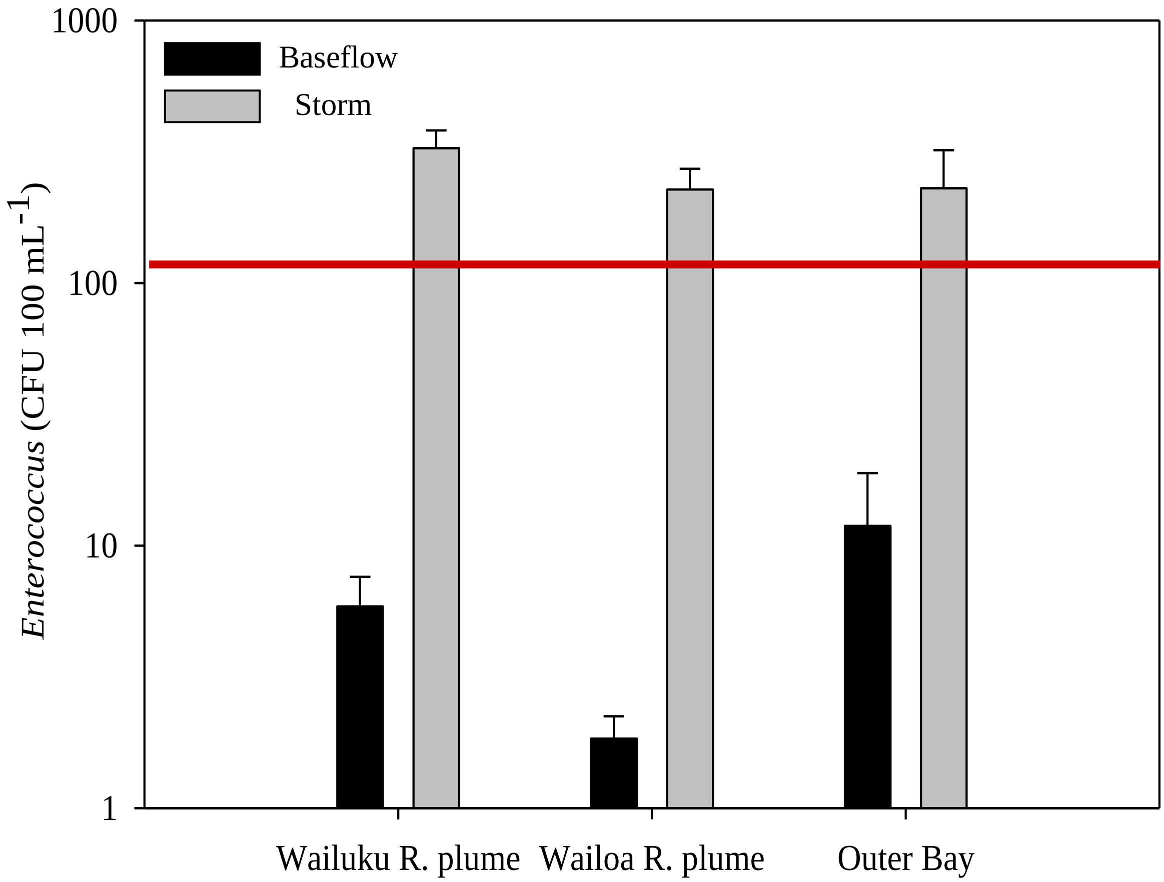


Figure 24. *Enterococcus* levels at three locations within Hilo Bay during baseflow and storm conditions in 2007. The red line indicates both Hawaii's and the USEPA's marine recreational *Enterococcus* standard (104 CFU 100 mL-1) for a single sample (Wiegner et al. 2012).

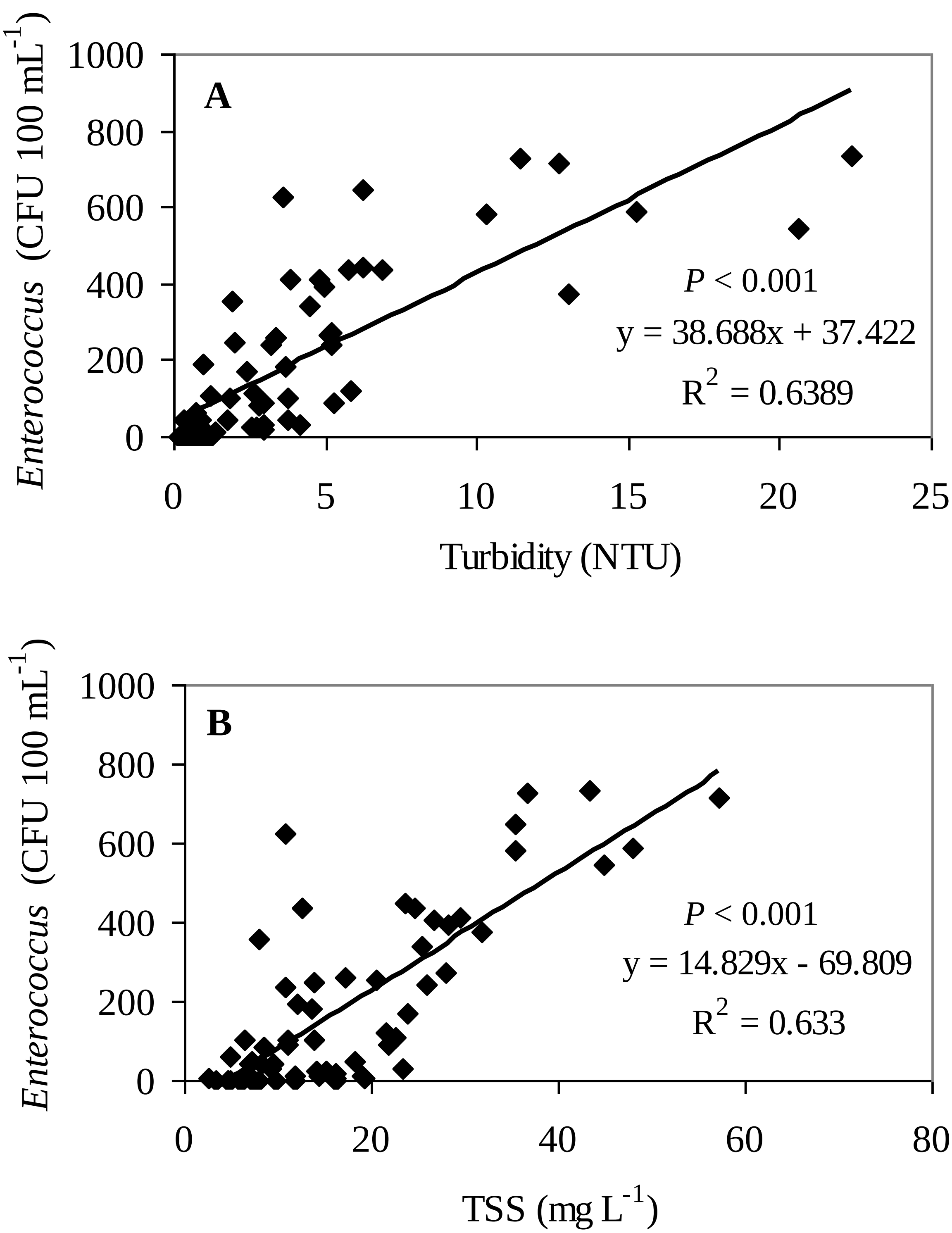


Figure 25. Relationship between *Enterococcus* levels with A) turbidity and B) total suspended solids (TSS) in Hilo Bay 2007. High R^2 values suggest that bacteria may be associated with soils from high runoff events and not sewage pollution (Wiegner et al. 2012).

Table 5. Coastal areas in the Hilo Bay that are listed as impaired according HDOH (2004). TMDL priority: L= low, M = medium, H = high.

Listed area	Pollutant(s)	Basis for listing	Station ID	Standard	TMDL priority
Wainaku to Paukaa	Nutrients Turbidity	Visual assessment Prior listing			M
Boat Landing	Chlorophyll *a*	Numeric assessment	001106	Wet/dry	M
Canoe Beach	Enterococci Turbidity	Numeric assessment	001138	Wet Wet/dry	M
Ice Pond	Total P Enterococci	Numeric assessment	001102	Wet/dry Wet	M
Lighthouse	Chlorophyll *a* Turbidity Enterococci	Numeric assessment	001107	Wet/dry Wet Wet	M
Offshore	Chlorophyll *a* Turbidity NO_3^-+NO_2- NH_4^+	Numeric assessment	001141	Wet/dry Dry Wet/dry Wet/dry	M
Honoli‘i Cove	Enterococci Turbidity	Numeric assessment	001110	Wet/dry Wet/dry	M
Leleiwi Beach Park	Total P Enterococci	Numeric assessment	001121	Dry Wet/dry	M
Puhi Bay	Turbidity Chlorophyll *a*	Numeric assessment	001130	Dry Wet/dry	L
Richardson Ocean Center	Chlorophyll *a* Turbidity	Numeric assessment	001136	Wet/dry Dry	L
Wailoa River	Enterococci	Numeric assessment	001132	Wet/dry	M

III. Value of Site for Research, Monitoring, and Resource Protection

A. Value of Site for Research: Hilo Bay is the piko of the Hilo community, used by many people for different purposes, including surfing, paddling, fishing, and traditional gathering, relaxing and researching. Each group uses a different, sometime overlapping, portion of Hilo Bay –Hilo Bayfront for paddling, Honoli'i Beach for surfing, and fishing and relaxing everywhere! Some locations are *wahi pana* (sacred places), including *Moku Ola* (Coconut Island), a traditional place of refuge, and *Kai Palaoa* at the mouth of the Wailuku River, the location of an *heiau* (alter) and a place where King Kamehameha I camped (Fig. 26). For each person that uses the estuary, the site where they return over and over has great significance, and they formally or informally, as individuals or as groups, care for the site and resources. Questions then arise about the environment, the cultural aspects, and coastal resource issues. Together, the Hilo Bay *Muliwa Hui* partnership strives to share with these communities the relationships that define and link cultural and ecological resources. With the support of NERRS, we will be able to advance this goal and expand with additional monitoring and research.

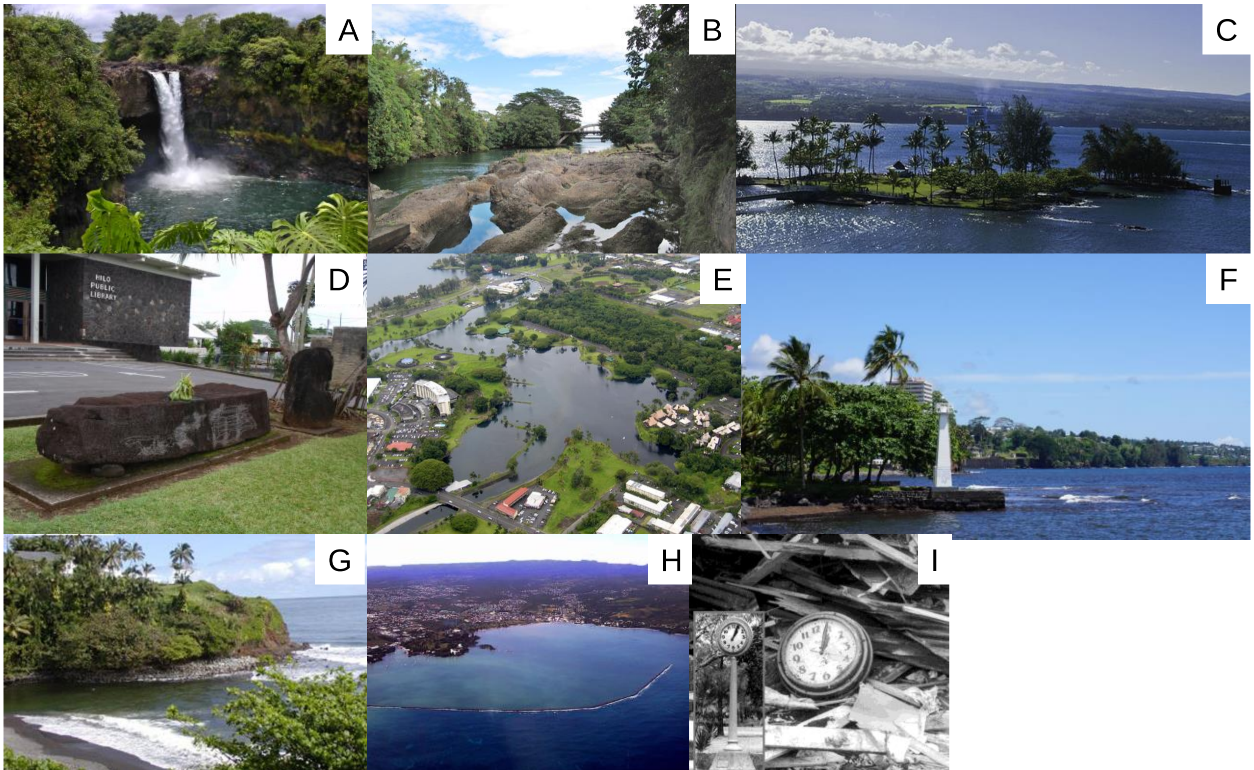


Fig. 26. Culturally and historically important sites in the Hilo Bay ahupua`a. A) Home of Kuna (a mo`o who tried to kill Maui's mother), Rainbow falls, Wailuku River; B) Wa1a-Kauhi (Maui's canoe), Wailuku River; C) Moku Ola, Kamehameha practiced cultural protocols here, Coconut Island, D) Naha stone, the stone Kamehameha lifted and fulfilled his prophecy of uniting the Hawaiian Islands; E) Royal Fish Ponds, Waiakea Fish Pond; F) Kai-paloaoa, ancient surfing area, Kamehameha often camped here, a historic battle was fought here, and a heiau with Liholiho's (Kamehameha's son) navel cord was once located here, Hilo Bay lighthouse, G) At Honol`i Cove, Maui was killed while chasing a girl as an eel; a priest came and killed the eel, H) Hilo Bay Breakwater built 1908 -1929, and I) Memorial to 1960 tsunami, clock marks the time when the tsunami hit.

There is a highly diverse characteristics within the proposed boundaries of the Hilo Bay NERRS that will provide many opportunities for research, monitoring, and resource protection site. Hilo Bay contains all three NERRS Program ecosystem types (Fig. 1). Temperature and salinity range from relatively cold freshwater in the streams to warm, full strength seawater in the deep portions of Hilo Bay and outside the breakwater (Figs. 14,15,16). Within the estuary, light penetration and water motion vary dramatically, with the large flow of the Wailuku River and the sheltered, groundwater-fed Reed's Bay representing the two extremes. Hilo Bay includes representative biotic and geologic sites, including coral on Blond Reef, algal-dominated rocky intertidal areas, and coastal marshes (Fig. 1). These ecosystems contain abundant native species of crustaceans, fish, snails, worms and insects, with 38 identified in the Wailuku watershed and 49 in Honoli'i watershed (*see* section II, E. Significant Faunal and Floral Support, 5. Native species). Many opportunities exist to address important habitat and resource management issues, including habitat restoration, wildlife management, and invasive species management, and are further discussed in Section IIIC.

A diverse literature on Hilo Bay and its environs is available, providing a wealth of background for developing new projects (Appendix I). Prior to the1990s, most data and analysis are contained in county, state, and federal reports associated with resource management, the development of the Port of Hilo, and other development projects. These reports provide a wealth of information on the environment, as well as providing a historical, social, and economic background on the use of Hilo Bay.

Today, research and education are tightly linked in Hilo Bay. Hilo Bay has been the natural laboratory for the Marine Science Department at UHH since 1992, when the Bachelor's of Arts in Marine Sciences was established by Hawai'i's Board of Regents. Students become associated with Hilo Bay in the first two introductory laboratories they take within the department (MARE 171L: Marine Biology Diversity laboratory; MARE 201L: Oceanography laboratory). The students continue to work on Hilo Bay in upper division classes (MARE 350: Coastal Methods and Analyses; MARE 353: Pelagic Methods and Analyses) where they learn how to do science from development of experimental designs, sample collection and processing, to data analysis and presentation in written and oral formats. Many of the majors then continue on to pursue senior thesis research projects on Hilo Bay, with 24 undergraduate senior research theses on Hilo Bay completed since 2004 (*see* Appendix II).

External funding of research projects has led to an increase in scientific publications. Infrastructure and faculty support for research were developed with the first NSF EPSCoR grant awarded to the University of Hawai'i System in 2003. There are now state-of-the-art analytical laboratories for ecosystem research (largely water quality), genetics, and spatial data analysis and visualization (*see* Appendix III). Additionally, a Master's program in Tropical Conservation Biology and Environmental Sciences (TCBES) was developed. With these improvements to UHH, research outside of courses on Hilo Bay became possible. Starting in 2004, one of the first extramural grants to study Hilo Bay's watershed was awarded and since then 11 additional awards have been obtained. Collaborations with the Hilo Bay Watershed advisory group, Hawai'i County, Hawaii State DAR were developed and from here Master's theses and peer-reviewed publications and professional reports were completed. Since 2007, four Master's Theses related to Hilo Bay have been completed, and since 2009, 12 peer-reviewed scientific articles have been published. (*see* Appendix IV). With these improvements to UHH, Hilo Bay is well poised for to become a NERRS.

B. Suitability of Site for Environmental Baseline Monitoring: Hilo Bay is an excellent site for gathering long-term baseline data on tropical estuarine systems. The watersheds of the Wailuku and Wailoa Rivers are 50% evergreen forest, much of which is native vegetation above 2,500 m and within the conservation land use category (over 70%) (Table 3). The lower elevation land cover is comprised of pasture, agriculture, and residential and commercial development (Table 3). Thus, within this watershed alone, the impacts of different land uses and vegetation on stream and estuarine water quality can be examined; some on these topics have already been examined (Wiegner and Tubal 2010, Michaud and Wiegner 2011, Wiegner et al. 2013). Additionally, the watershed elevation spans from sea level to 4200 m and whose temperature ranges from 77 F to 5 (Juvik and Juvik 1998), these differences will allow for climate changes on forest ecosystem structure and function to be examined on a similar substrate. This experimental design has been used Stanford University and others already (*see* Vitousek 2004). Currently, the USDA Forest Service, Institute for Pacific Island Forestry has established a series of stream sites that are located at a similar elevation and have similar native vegetation, but differ in the amount of rainfall they receive. This series of stream site is being used to examine how changes in precipitation affect stream ecosystem structure and function, and collaborations with several members of this working group already exist. Note, these sites are adjacent to the proposed boundaries for the Hilo Bay *Muliwai* NERRS and sites within the NERRS could be used to extend the gradient into wetter climate.

Hilo also has a pronounced wet and dry season and this can be seen in the rain and stream discharge data. The changes in rainfall and consequently stream discharge affect water quality in Hilo Bay (Wiegner and Mead 2009, Wiegner et al. 2012). Data from the Hilo Bay Water Quality Buoy show that the storm / baseflow hydrographic cycle of the Wailuku River are tightly coupled with salinity and turbidity in Hilo Bay (Fig 27), affording the opportunity to monitor linkages between rainfall, river flow, and estuarine habitat. This type of connection was recognized by the ancient Hawaiians; they had a description for rains that caused nehu to be plentiful in Hilo Bay: *Ka ua he'e nehu o Hilo*.

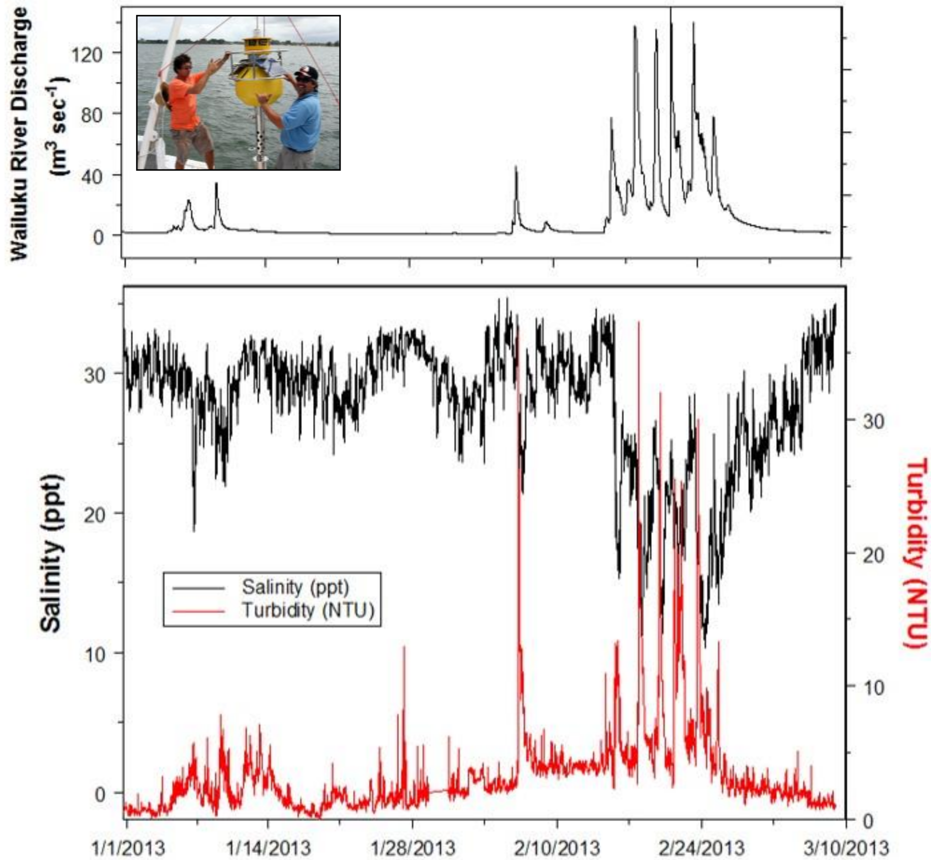


Fig. 27. Wailuku river discharge (USGS 16704000, top panel) and Hilo Bay surface salinity and turbidity (HB water quality buoy) for a 2.5 month period encompassing base and storm flow conditions. The tight coupling between river flow, salinity, and turbidity in Hilo Bay is evident (Adolf et al. unpublished data).

Additionally, the closure of Hilo Bay to commercial fishing makes this a good environment for monitoring fish populations over long time periods.

The availability of monitoring equipment (HB water quality buoy, HF radar for current monitoring, PacIOOS wave buoy outside Hilo Bay, USGS gages on Wailuku and Honoli'i rivers, tsunami-capable water level gage in Hilo Harbor), as well as the close proximity of UHH Marine Science and Hilo DAR, will help facilitate long-term baseline monitoring in Hilo Bay *Muliwai*.

C. Ability to Address Key, Local, State, and Regional Management Issues.

1. Coastal Zone Management (CZM) Issues. Hilo Bay watershed is an ideal location to address key, local, state, and regional coastal zone management (CZM) issues because it has diverse land use within its watershed and along its coastal line, and use of its water body. In fact, all of the Hawai'i State's CZM initiatives can be examined using Hilo Bay watershed as a model system. These initiatives include: adapting to climate change, coastal hazards, coastal non-point source pollution, community-based resource management, impacts of stormwater, Hawaiian traditional and customary gathering rights, and best rural management practices.

One of the reasons why Hilo Bay is an ideal system for studying CZM issues is because of its diverse land use within its watershed (Table 3). The land use ranges from native to invaded forests, agriculture/silviculture, pasture, and developed (residential and commercial) areas, and within these areas, there are native and invasive marine, freshwater, and terrestrial species. CZM issues that could be examined given this diverse matrix include, studies examining: 1) restoration of native terrestrial and aquatic plants and juvenile fish habitat, 2) removal of invasive terrestrial, freshwater, and marine species, 3) impacts of development on coral reefs, 4) wetland development, mitigation, restoration, and creation, 5) waterfowl and other wildlife management, 6) best management practices for terrestrial, freshwater, and marine habitat protection and management, 7) best management practices to limit impacts from agriculture, silviculture, or development activities, 8) best methods to control pestiferous insects or undesirable vegetation, 9) effects of pollutants from point and non-point sources on water quality and living resources, and 10) impacts of sea level rise on coastal and terrestrial habitats, and on low-lying communities.

Hilo Bay is also a hub for recreation for the local community and visitors. They use it for paddling, fishing, surfing, swimming, and scuba diving. Fishing is conducted from shore, as well from boats which are launched from the small boat harbor. CZM issues relevant to recreation that could be studied here include: 1) beach management and shoreline erosion, 2) commercial and recreational fisheries, 3) waterborne-disease and infections from sewage inputs (cesspools, septic tanks, and sewage spills), as well as warm-blooded animals (leptospirosis).

Hilo Bay is the primary port on Hawaii Island. It is the center of inter-island and overseas shipping operations, as well as port-of-call for cruise ships. A $55 million inter-island cargo terminal is currently being built to accommodate increased commerce and travel to Hilo. In 2012 alone, cruise ships docked 130 times bringing 286,584 passengers. CZM issues that could be examined with regards to this include: 1) dredging and spoil disposal, as well as beneficial uses of dredged materials, and 2) pollution related to harbor use (i.e., oil, grease, toxic chemicals, heavy metals).

Given Hilo's geography, topography, and geology, Hilo experiences many different types of natural disasters, including: tsunamis, hurricanes, flooding, storm surge, and earthquakes. Hilo is often called the 'tsunami capitol of the United States'. In 1946, a tsunami from the Aleutian Islands killed 160 people, while another one in 1960 killed less people (61) as a result of the establishment Pacific Tsunami Warning Center. To reduce the amount of damage and loss of life from tsunamis, Hilo condemned an area along the Bay front and Wailoa River that was once a mostly-Japanese neighborhood (Shinmachi) and converted into park land in 1969 (Fig. 28). This area is now known as the Wailoa River State Recreation Area. Other smaller tsunamis have hit Hilo since 1960, with the most recent one being in 2012; however, the town has been fortunate that little to no damage was incurred and there was no loss of life. Thus, Hilo is

Figure 28. Pictures of Shinmachi A) before the 1960 tsunami, B) during the tsunami, C) after the tsunami, and D) today –Wailoa River State Recreational Area.

therefore a model site for examining tsunami mitigation.

Hilo is also the third rainiest city in the United States as a result of the moisture-rich trade winds rising in altitude and cooling as they come into contact with Mauna Kea and Mauna Loa. Average annual rainfall in Hilo is 3,220 mm (127 inches), with the greatest amount of rainfall recorded in 24 h being 692 mm (27 inches) (Fig. 29). Flooding and stormwater runoff are therefore common events in Hilo (Figs. 13, 30). Two of the water quality parameters Hilo Bay is listed for on the USEPA's 303 d list, turbidity and fecal indicator bacteria, are associated with storm runoff. Therefore, Hilo Bay is ideal for examining flooding and stormwater issues. Storms also bring coastal surge, which often result in the Bayfront Highway being closed temporarily. Additionally, it is predicted that as the ocean waters warm around Hawai'i Island, a greater number and more powerful storms will make landfall in Hilo.

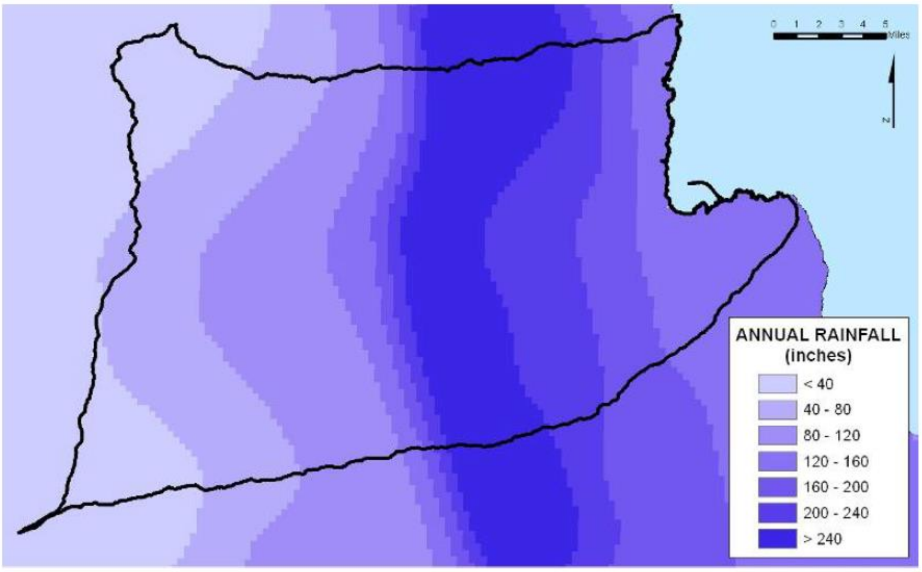


Figure 29. Annual rainfall amounts in the Hilo Bay watershed (USDA NRCS 2009).

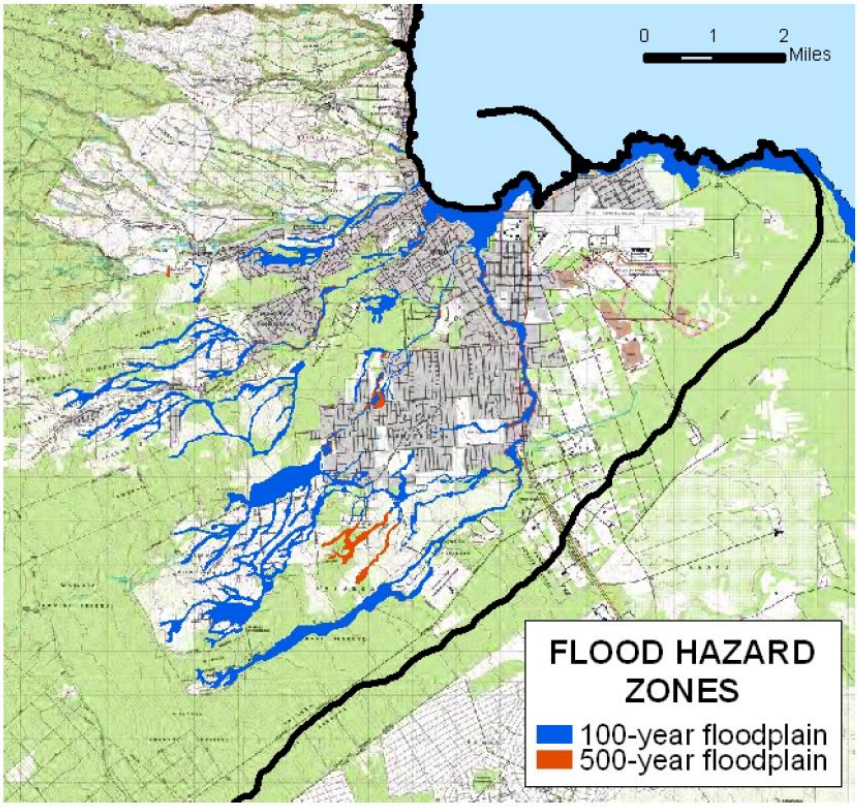


Figure 30. Flood zone hazard map for the Hilo Bay watershed (USDA NRCS 2009).

Hilo, with its many renewable energy sources, is an ideal location to examine the development of local, sustainable energy supplies. Currently, there are two hydroelectric power plant located on the Wailuku River. It is predicted that Hawaii will become drier with global warming and it will be necessary for Hilo to develop additional renewable energy sources. These sources of energy could include offshore wind and wave energy.

2. Forest Management Related to CZM. There are also many watershed issues related to CZM that can be studied in the Hilo Bay watershed. One of the greatest threats in the headwaters of the watershed are hoofed animals (ungulates: pigs, goats, mouflon, sheep, and cattle). They destroy native vegetation and prevent it regeneration through consumption, while accelerating the invasion of weed species through direct dispersal of seeds on their coats and droppings. Pig wallows also provide mosquito-breeding habitat that promotes the spread of avian malaria and pox –the two most deadly diseases to native birds, and human diseases. In some landscapes, ungulates cause severe and extensive erosion, directly affecting forested uplands and near-shore coral reefs. Cumulatively, ungulates cause the decline of intact native ecosystems which affect watershed functions and jeopardize the future existence of rare and endangered plants and animals.

Another threat in the Hilo Bay watershed is the uncontrolled spread of invasive non-native plants. These plants displace distinctive native flora, resulting in loss of species diversity and pronounced and permanent changes to ecosystem function like primary production and nutrient cycling. Many invasive species completely replace native vegetation resulting in total loss of native habitats.

Smaller animals (feral cats, rats, mongoose, dogs, house mice) can cause serious damage to watersheds too. They can affect water quality by serving as vectors of water-borne diseases.

IV. Suitability of the Site for Training, Education, and Interpretation

A. Diversity and Quality of Training, Education, and Interpretation. There are several exceptional educational and outreach programs that use Hilo Bay and its watershed as a '*natural laboratory'*. These programs are run through HCC, UHH, EKF, MDC, TMA, and ʻImiloa Astronomy Center. Future collaborations between the Hilo Bay NERRS with these existing programs and these institutions would provide educational experiences to students that can not be matched elsewhere in the United States. Below, we describe some of these programs.

1. HCC. At HCC, programs relevant to NERRS include: the Forest TEAM (tropical forest ecosystem and agroforestry management), Hawaiʻi lifestyle, Hawaiian studies, hula, *lawaiʻa* (fishing), and *mahiʻai* (kalo farming).

2. UHH. At UHH, there are several departments and programs that have an active presence in Hilo Bay. These departments and colleges include: Marine Science, Biology, Geography and Environmental Science, Geology, Anthropology, Tropical Conservation Biology and Environmental Science (TCBES) Graduate Program, College of Agriculture, Forestry, and Natural Resource Management, College of Pharmacy, and College of Hawaiian Language and Literature. There are also several programs run through UHH whose missions' are to increase engagement of Hawaiian and Kamaʻaina students (K-12 and undergraduates) in environmental sciences. These programs include: Pacific Internship Programs for Exploring Science (PIPES), Nā Pua Noʻeau, and Kealoha STEM program. Below, we elaborate on a few of these programs.

a. Marine Science Department. This department has an active undergraduate education and research program in Hilo Bay. The department offers BA and BS degrees and is dedicated to offering as many hands-on experiential educational opportunities as possible to undergraduates interested in marine science and conservation. All of the BS students are required to complete a senior research thesis project and since 2004, 24 have focused on Hilo Bay (*see* Appendix II).

b. TCBES Graduate Program. This graduate program is a 30-36 semester hour program Master's degree program, and currently is the only one in the University of

Hawai‘i system that trains students in the interdisciplinary fields of conservation biology and environmental science. Students from this program have gone on to work at natural resource agencies within the State and federal government, as well as continue on in academics. To date, five MS theses have focused on Hilo Bay and several publications have resulted from these projects (*see* Appendix IV).

c. PIPES Program is a university undergraduate level program housed within the Office of Research. *PIPES is committed to increasing the recruitment and retention of local students, especially those of Native Hawaiian ancestry, into fields of study, and ultimately careers, related to the natural resources of Hawai'i and the Pacific region.* PIPES includes an NSF-funded Research Experience for Undergraduates (REU), the UH Hawaiian Internship Program and the Micronesia and American Samoa Student Internship Program (MASSIP). PIPES matches select interns with research, management and environmental education internships across the state and in the Pacific. The internship experience is project-based and includes proposal and report writing, oral presentations, field trips, speakers and attendance to the annual Hawai‘i Conservation Conference in Honolulu. PIPES also organizes OCEAN DAY each year, a community event to increase public awareness about the ocean and watershed resources.

d. Kealoha STEM Program. The goal of Keaholoa STEM Program is to increase the number of UHH students of Hawaiian ancestry who take courses or major in science, mathematics and technology fields. They do this through a summer intensive tutorial in math and science, classes offered during the academic year, and paid internships.

e. Nā Pua No‘eau was established in 1990 at UHH for the purpose of increasing educational enrichment opportunities for Native Hawaiian children (K-12) throughout the state of Hawai‘i. The center has created an education system that strengthens the academic ability and potential of Hawaiian students through a research based foundation. Nā Pua No‘eau integrates an instructional model that is congruent with the history, culture, and perspective of the Hawaiian people. Nā Pua No‘eau is a pioneer in changing the paradigm to assure that the success of students and families are strengthened by their connection to culture, family and community. Nā Pua No‘eau succeeds by providing hands-on interactive culturally based learning.

3. EKF. At the EKF, traditional practices including management practices are taught through workshops and site visitations along the coastline of Honohononui as well as the *lo’i* (taro patches) in Waipi’o valley. EKF services students of all ages and has worked closely with UHH, HCC, The Kamaehameha Schools, BISAC and O Ka Aina (a CI funded program). Current EKF programs include:

> **a. Noho Papa extended day learning program.** The Noho Papa extended day learning program introduces our students to various fields while linking them to their immediate environment. The program services students K-12 and offers a variety of traditional and contemporary fields of study including digital design and sustainability, coastal and land management, fish and produce farming, food preparation and nutrition, engineering and business, and traditional and contemporary arts.
>
> **b. Ka ‘Umeke Ka’eo Public Charter School.** EKF works very closely with their resident charter school KUK, providing support, facilities and

environments to enhance the education of these individuals. KUK is a Hawaiian language immersion school servicing grades K-12 located in Keaukaha.

c. Papaku Makawalu. EKF offers a series of workshops involving the concept of *papaku makawalu* which is a traditional way of looking at, organizing and understanding our environment.

d. Halau o Kekuhi. *Halau o Kekuhi* is a traditional formal hula school passed down through matrilineal descent. The hula school is internationally known for its *'aiha'a* or raw and bombastic style of dance characteristic of Hawai'i Island's creative forces.

4. Mokupāpapa Discovery Center. MDC is the primary educational facility for the Papahānaumokuākea Marine National Monument. The center was established in 2003 to interpret the natural science, culture, and history of the Northwestern Hawaiian Islands. Their goal is to "bring the place to the people" and spur greater public awareness of the region and relevant ocean conservation issues. The center receives an average of 60,000 visitors per year, with approximately half of these being local residents and the other half visiting from elsewhere. They offer free admission to the public and free educational programs to a wide range of groups and institutions. Coinciding with their 10 year anniversary, MDC has relocated to a new, larger space in Hilo to expand their programs and offerings. They envision a multi-use complex that will feature additional classroom spaces, a theater, and a training center that will host workshops for groups from all corners of the globe working in marine management and conservation.

5. Three Mountain Alliance. Imi Pono no ka ʻĀina (ʻImi Pono) is the environmental education and out-reach program for the TMA watershed partnership. Since its creation 1999, the program has provided conservation-themed programs for students and teachers, led community service trips, and participated at community events across Hawaiʻi Island. The diversity of native landscapes within the TMA provides unparalleled opportunities for individuals to learn about and experience the ecosystems that undoubtedly sustain life here in Hawaiʻi. Coupled with cultural and scientific knowledge, practices, and activities, ʻImi pono strives to provide meaningful experiences that create and strengthen the relationship between man and nature. A philosophy that is shared in all our programs is, *I ola ʻoe, I ola mākou nei.* This *ʻōlelo noʻeau* speaks to the inter-relatedness of all things, that we are dependent on each other, and that our actions, direct or indirect, affect the well being of all life. ʻImi Pono programs can be divided into the following categories:

a. Student Environmental Education Program. The program invites students in grades 6-12 to take part in programs during summer, spring and fall breaks where they travel to different natural areas across the island and engage in hands-on activities such as native plant propagation, invasive species control, and reforestation. Students also complete a curriculum that integrates Hawaiian culture, science, and current conservation issues.

b. Teacher Environmental Education Program. Imi Pono's teacher education workshops encourage educators to incorporate environmental education into their curriculum and to promote community stewardship of our natural resources. The workshops include field-based experiential learning with themes of Hawaiian culture, science, and current conservation issues. Teachers receive lesson plans and activities designed for the classroom that are based on Hawaiʻi State Department of Education Content and Performance Standards. After completing the workshops, teachers and their students are eligible to participate in service projects and specific TMA sites.

c. Community Service Work. Majority of the programs service work takes place at Kamehameha Schools (KS) Keauhou Forest. Approximately 15 workdays per year are held, each focusing on different restoration activities including reforestation (outplanting native species), seed collection, weed control, forest bird monitoring, and outplant maintenance/monitoring. Past groups include: DOE and Hawaiʻi Public Charter Schools, UHH and HCC classes, and KS alumni, staff, and students. On occasion, service work takes place on other TMA partner lands.

d. Community Out-reach Events. ʻImi Pono holds education booths at community events such as the UHH Earth Day, the Hawaiʻi County Fair, the Merrie Monarch Parade, Pūlama Mauli Ola at Nāwahīokalaniʻōpuʻu, the Roi Round-up, and other events upon request. Our education booths provide visitors with information about the TMA and ʻImi Pono, how protecting native species protects Hawaiʻiʻs watersheds, threats to Hawaiʻiʻs watersheds, and ways they can get involved. Upon request, ʻImi Pono staff give in-class presentations for school groups and community groups. Some presentations topic include the basics of Hawaiʻiʻs natural history, ʻwhat is a watershed?ʼ, threats to native ecosystems, and watershed partnerships.

6. ʻImiloa Astronomy Center. `Imiloa is a gathering place that advances the integration of science and indigenous culture. They host school field trips (K-12), which can include planetarium shows, the exhibit hall, tours through the native landscape garden, and classroom activities. They also offer an intersession hands-on science programs (K-3). On their website, educational materials are available they include: pre- and post-field trip activities, sky navigation guides, and answers to cosmic questions.

B. Diversity and Availability of Target Audiences. <u>The 2000 US Census data show that Hilo was the most ethnically diverse city in the US.</u> Of the 42,263 people living in Hilo as of 2010, the ethnic composition was 34% Asian, 18% Caucasian, 14% Native Hawaiian and Pacific Islander, 0.5% African American, 0.3% Native American/Alaskan, 0.6% other races, and 33% from two or more races.

Within proposed boundaries of the reserve there are 26 schools, serving approximately 7000 students. Specifically, there are nine public elementary schools: 1) E.B. DeSilva (381), 2) Haaheo (6), 3) Hilo Union (446), 4) Chiefess Kapiolani (388), 5) Kaumana (231), 6) Keaukaha (326), 7) Kalanianaole (*see* enrollment in intermediate school list), 8) Waiakea (840), 9) Waiakeawaena (746); three intermediate schools: Hilo (492), Waiakea (864), and Prince Jonah Kalanianaole (264); and two high schools: Hilo (1310) and Waiakea (1226). There are three charter schools: Connections (343), Ka Umeke Kaeo (Hawaiian Immersion, 243), Ke Ana Laʻahana (85) and seven private schools include: E Makaala (80), Haili Christian (242), Hale Aloha Nazarene (107), Mauna Loa (23), and St. Joseph (133).

Hilo has two institutions of higher education serving approximately 8,000 students. Hawaii Community College (HCC) has 3,917 students (Fall 2010). The student body's composition is 46% Hawaiian/part-Hawaiian, 17% Caucasian, 13% mixed, 8% Filipino, Other 7%, Japanese 6%, and Pacific Islander 3%, with males and females comprising 45% and 55%, respectively. At HCC, the majority of the students are from Hawaii State (96.3%), with the remainder coming from the US mainland (1.4%), US-affiliated territories (0.3%), other countries (1%) foreign, and unknown(1%). The purpose of HCC is to prepare students to meet community employment needs through career and technical training programs. Programs at HCC that are relevant to NERRS include: the Forest TEAM (tropical forest ecosystem and agroforestry management), Hawai'i lifestyle, Hawaiian studies, Hula, *lawai`a* (fishing), and *mahi`ai* (kalo farming).

The second institution of higher learning is UHH, serving 4,157 students (Fall 2012) across six colleges. It is a comprehensive university with undergraduate and graduate programs. The student body's composition is 27% caucasian, 24% Hawaiian/part-Hawaiian, 13% mixed, 6% Pacific Islander, 6% Filipino, 9% Japanese, 3% Chinese, and Other 13%, with males and females comprising 42% and 58%, respectively. The majority of students at UHH are from Hawaii State (71%), with the remainder coming from the US Mainland (20%), US-affiliated territories (5%), foreign countries (4%), and other (2%). UHH ranked 6th nationwide for campus ethnic diversity according to US World Reports (2004). Departments and programs at UHH that are relevant to NERRS include:

Therefore, educational and outreach programs associated with the Hilo Bay NERRS will reach a diverse audience and serve to further introduce under-represented groups to fields of environmental science and management.

C. Opportunities for Interpretation and Historical Sites. Historic resources: *Moku Ola* (Island of Life) known as Coconut Island is an ancient healing complex, where those who fell out of social order escaped to undergo ritual cleansing (Fig. 26). This significant cultural site is in the center of the project area and serves as the *piko* (umbilical) connecting us to our environment. Significant place names mentioned in our chants include Kanukuokamanu the point makai of the Wailoa boat ramp, Kaipalaoa the area near the Hilo light house, Kaluakanaka at the north side of the mouth of Wailuku river, and Kawaaomaui located near the mouth of Wailuku river associated with the gods Maui and Hina (Fig. 26). Haleolono fishpond located in Honohononui along the coastal area near Keaukaha is associated with a signifant Hilo chief, Kalaninuiiamamao (Fig. 9). The creation chant known as the kumulipo was created in his honor and is closely linked to this area but more importantly it helps us understand the connection between all living things. The Hilo Breakwater was determined to be eligible for inclusion in the National Register of Historic Places by the Keeper of the Register in 1980. The breakwater was deemed significant in areas of commerce and transportation for the vital role it played in the development of the port of Hilo, the historic main port of entry for Hawai'i Island. The breakwater is associated with events that facilitated the railroad and port expansion. The breakwater is 2 miles long and is the longest one in the state.

V. Acquisition and Management Considerations

A. & B. Land Ownership, Publicly Owned Lands and Feasibility of Land Acquisition. There are five main types of land owners within the watershed, with about 76% of the areas under public ownership by the County, State, or Federal Government. Most of the public lands are part of the Hawai'i system of reserves and parks (NRCS 2009). Major private land owners control 13%, including Kamehameha Schools, Hawai'i Forest Preservation LLC, and Hawai'i Forest Products. Much of the other landowners are small urban designated lands within the city, 11%. All waters within the proposed boundary are under State jurisdiction and active management is in place for the majority of lands.

C. Availability of Facilities

1. The University of Hawai'i at Hilo (UHH). Located less than 2 miles from Hilo Bay, UHH has a vibrant, multicultural campus. UHH is accredited by the Accrediting Commission for

Senior Colleges and Universities of the Western Association of Schools and Colleges (WASC). While the University's primary focus is undergraduate education, it also offers several graduate degree programs in focused areas at both the master's and doctoral levels. These include undergraduate degrees in Marine Science, Aquaculture, Biology (Cell and Molecular Track and Ecology, Evolution and Conservation Track), Anthropology, and Geography. Graduate programs include, Tropical Conservation Biology and Environmental Science (TCBES) Graduate Program and the Doctor of Pharmacy. A total of 4,157 students were enrolled in Fall 2012. Extramural funding in the fiscal year 2009 amounted to $20.1 million. This amount demonstrates UHH's robust commitment to research and scholarship.

The main UHH campus offers a wide range of facilities that are managed by the Hilo Conference Center. Classrooms (tables and chairs) with seating capacity up to 136 people. Each classroom has computers with internet connection, a screen and LCD projector. Several classrooms are fit with PolyCom for distance learning instruction. Computer classrooms that seat up to 24 students are also available. Laboratory classrooms are also available, including a wet lab for students and faculty to can carry out chemical analyses of marine sediment, water and organisms. A Dining Hall seats up to 441 people, and includes a stage, large projection screen and a professional audio system. UHH Dormitories have over 400 beds with internet connections, some with kitchens, and lounge areas. Wireless internet is available across campus. The Edwin H. Mookini Library serves both UHH and HCC. The library includes a 93,000 ft^2 library with 9 group study rooms, 130 personal computers for students, and a library classroom with 26 computers, and a Hawai‘i Interactive Televion System (HITS) Classroom. The physical collection includes 234,560 book volumes and 71 current print serial titles, while the electronic resources boast 44,000 online periodical titles, 103,704 electronic books and 148 electronic databases.

a. Kalakaua Marine Education Center (KMEC). KMEC works in conjunction with the UHH Marine Science Program to develop and maintain cooperative marine research and education programs for undergraduate and graduate students. To this end, one of the main responsibilities of KMEC is to maintain and operate a fleet of small vessels that are used in marine science education and research, including a 36' Force Catamaran *Makani aha*; an 18' Larsen outboard *Kaimi*, two inflatables (10' and 12'), and the 25-ft Force Marine Runabout *April Maru*. They also run the scientific diving course (QUEST, Quantitative Underwater Ecological Survey Techniques) for the University system. To do this, UHH has a dive safety officer, a compressor for filling SCUBA tanks, and 70 or more SCUBA tanks.

b. Pacific Aquaculture and Coastal Resources Center (PACRC). PACRC has two facilities in Hilo, the primary one is a 12.5-acre coastal site at Keaukaha, adjacent to the Hilo Harbor, and the second site is an located in Pana‘ewa (UHH Agricultural Farm Laboratory), six miles inland. The Keaukaha facility focuses on ornamental fish culture, the cultivation of pearl oysters and other shellfish and its grounds include: 1) a water quality laboratory, 2) a marine mammal rehabilitation facility, 3) greenhouse-like structures which contain aquaculture tanks, 4) seawater and freshwater wells, and 5) a few offices for staff. The focus at the Pana`ewa facility is on quarantine, health management and integrated agriculture-aquaculture farming systems. On these grounds, there is 1) a pathology laboratory, 2) quarantine facilities, 3) a freshwater fish hatchery. The quarantine facilities are state-of-the-art allow for work on exotic species. Additionally, the nutrient-enriched waters generated from the aquaculture facility are used in aquaponics and they have been shown to improve efficiency and profitability of local farms.

c. UHH Analytical Laboratory: The UHH Analytical Laboratory was developed during the first NSF EPSCoR Track I grant and it is still partially funded by the third EPSCoR Track I grant. The laboratory employs a full-time manger and technician, plus a part-time research assistant. Equipment at the facility includes: 1) a Pulse Autoanalyzer III (with channels for nitrate, ammonium, silica, and phosphate), 2) a Shimadzu TOC-V CSH, TNM-1 Total Organic Carbon and Nitrogen Analyzer, 3) Costech Elemental Analyzer (carbon, nitrogen, hydrogen on solid samples), 4) Thermo-Finnegan Delta V IRMS (stable isotope analysis for carbon and nitrogen), 5) a Varian Vista MPX ICP-OES Spectrometer (for elemental analysis), and 6) an ion chromatograph (for anions). Other pertinent equipment at the facility are: fluorometers, spectrophotometers, drying ovens, muffle furnaces, an autoclave, electronic balances, a microbalance, refrigerators, freezers, a refrigerated centrifuge, glassware, vacuum pumps, and pipettes. For fieldwork, field meters for measuring conductivity, pH, dissolved oxygen, temperature, light levels, and turbidity are available at the facility.

d. UHH Spatial Data Analysis and Visualization Laboratory: This facility was developed during the first EPSCoR Track I grant and is still fully funded by the third EPSCoR Track I grant. SDAV Laboratory consist of two computer-based facilities: an instructional lab, supporting professional development and the undergraduate and graduate-level geospatial science curriculum, and a research service center enabling the discovery and dissemination of new scientific relationships. SDAV, established in 2001, now comprise 35 workstations, physical and virtual server complex on a 10-GB backbone, and a staff of five with expertise in system administration, software engineering, modeling, geospatial technologies and web design. SDAV creates and hosts an array of services for University of Hawaiʻi researchers from secure simple shares and complex databases to public accessible intuitive web-based atlases for sharing scientific knowledge.

e. UHH Core Genetics Laboratory: The UHH Core Genetics Laboratory was developed during the first NSF EPSCoR Track I grant and it is still partially funded by the third EPSCoR Track I grant. The facility functions as a service laboratory and offers technical training in genetics, as well as DNA sequencing and DNA fragment separation and detection services. The laboratory employs a full-time manger. Equipment at the facility includes: 1) Applied Biosystems 3500 Genetic Analyzer, 2) Ion Torrent Personal Genome Sequencer, 3) Beckman Coulter CEQ 8000 Genetic Analysis System, 4) Beckman Coulter Biomek 2000 Laboratory Automation Workstation, 5) LiCor Biosciences 4300 DNA Analyzer, 6) LiCor Biosciences Odyssey System, 7) MJ Research PTC-200 Thermal Cycler, 8) Bio-Rad C1000 Thermal Cycler, 9) Beckman Coulter Allegra 25R Centrifuge, 10) Spectramax 190 Microplate Reader, 11) Agilent 2100 Bioanalyzer, 12) Axon 4200 GenePix Microarray Scanner, 13) Applied Biosystems StepOne Plus Real-Time PCR, and 14) a Nonodrop spectrophotometer. In addition, workshops and training sessions are offered regularly to introduce current molecular and biotechnological to techniques to anyone in the community and reference materials and analytical software are available to all.

f. U.S.G.S. Cooperative Fishery Research Unit. The unit is slated to be housed at UHH starting in 2014. The search for the directo has been on hold since the initiation of the federal government sequestration.

g. University Research Park.

1) USDA Forest Service –Institute for Pacific Islands Forestry (IPIF). IPIF has been a center of research and technology transfer since 1967. The Institute addresses information needs to support the management, conservation, and restoration of natural forest and wetland ecosystems and landscapes throughout the Pacific. The Institute's area of responsibility includes seven U.S.-affiliated political entities in the Pacific: the State of Hawai'i, the Territory of Guam, the Territory of American Samoa, the Commonwealth of the Northern Mariana Islands, the Republic of the Marshall Islands, the Federated States of Micronesia, and the Republic of Palau. The focus of research and technological assistance centers on Hawai'i and other islands of the Pacific, but results are applicable to many tropical and temperate ecosystems of the world, including the U.S. mainland. The four areas of research at the Institute are: 1) conservation of biodiversity, 2) ecosystem function and health, 3) fire and fuels, and 4) urban ecosystems and social dynamics. At their institute, there is a laboratory and greenhouse for research. They also have an experimental forest which is located just beyond the boundaries of the proposed Hilo Bay NERRS. Collaborations already exist between many of members of the Hilo Bay NERRS Working Group and IPIF. They are therefore a natural partner for NERRS to address issues surrounding watershed function and management.

2) ‘Imiloa Astronomy Center of Hawaii. ‘Imiloa is a gathering place that advances the integration of science and indigenous culture. Their diverse exhibits, programs, and events harness leading technologies, environmental resources, and cultural practitioners to engage children, families, and communities in exciting ways. They are committed to improving the quality of life of the people of Hawai‘i Island and state. Through strategic partnerships with programs of the University, Hawai‘i - based observatories, local businesses and schools, they create opportunities that strengthen career awareness and workforce development, and contribute to our community sustainability. Their facility includes: exhibit halls, a planetarium, a native garden, restaurant, and museum store. ‘Imiloa is a natural partner for NERRS. They share the common goal of science education. Through areas of overlap between the two programs, like way-finding of Pacific Islanders, exhibitions, events, programs can be developed together.

3) College of Tropical Agriculture and Human Resources (CTAHR) - Komohana Agriculture Complex. The mission of CTAHR Hawai‘i Island is to promote the success of Hawai‘i's agriculture, strong and healthy communities, and sound stewardship of Hawa‘`i's land and natural resources through research and extension programs. Their faculty and staff conduct educational and applied research programs to increase diversified agriculture, promote safe and healthy food products, control invasive species, enhance environmental conservation, and train adults and youths in leadership and life skills

4) USDA Pacific Basin - Agriculture Research Center (PBARC). The mission of PBARC is to develop basic and applied information to strengthen agriculture in Hawai‘i and the Pacific Basin in an environmentally acceptable and sustainable manner by managing and developing tropical plant genetic resources, developing new technologies, and germplasm for improving crop productivity by reducing physiological and disease constraints, developing and demonstrating appropriate strategies for managing crop pests, providing economically viable technologies for controlling quarantine pests, ensuring product quality and safety, and increasing economic returns.

5) Ku Kahau Ula - UH Institute for Astronomy. This institute conducts research into galaxies, cosmology, stars, planets, and the Sun. Faculty and staff are involved in education and development and management of observatories on Mauna Kea and Haleakala.

2. NOAA/ Mokupāpapa Discovery Center (MDC). MDC is the primary educational facility for the Papahānaumokuākea Marine National Monument. The center was established in 2003 to interpret the natural science, culture, and history of the Northwestern Hawaiian Islands. Their goal is to "bring the place to the people" and spur greater public awareness of the region and relevant ocean conservation issues. The center receives an average of 60,000 visitors per year, with approximately half of these being local residents and the other half visiting from elsewhere. They offer free admission to the public and free educational programs to a wide range of groups and institutions. Coinciding with their 10 year anniversary, MDC has relocated to a new, larger space in Hilo to expand their programs and offerings. They envision a multi-use complex that will feature additional classroom spaces, a theater, and a training center that will host workshops for groups from all corners of the globe working in marine management and conservation.

The potential designation of Hilo Bay as a NERRS will only increase their capacity to engage with visitors, students, and the local community. This can be accomplished by raising awareness and educating the public about the value of the unique natural resources of Hilo Bay and its adjacent watershed through educational programs and interactive exhibits, and comparing them to the pristine ones of the Papahānaumokuākea Marine National Monument.

3. Division of Aquatic Resources (DAR) Wailoa Fisheries Research Station (WFRS). WFRS is located in Hilo and is a research outpost managed and operated by the DAR, and funded by Federal Aid in Sports Fish Restoration (Dingell–Johnson Act). Originally built for culturing alternative bait fishes for the local tuna fishery, WFRS has evolved into a research-based station that facilitates projects focusing on estuarine fish biology, juvenile fish habitat enhancement, and various estuarine monitoring projects throughout the state. WFRS also provides its facilities and logistical support to visiting scientists and collaborating researchers. In addition, WFRS supports public volunteer opportunities, student internships, and public outreach. Features of WFRS include: 1) 17,000 sq ft fenced property, 2) four 16' diameter, 6000 gallon aquaculture tanks, six 12' diameter, 3000 gallon aquaculture tanks, 3) three hp Haywad Super II Pump with Hayward Pro Series Sand Filter, 4) a wet laboratory, 5) two office modules (44' and 32') with a conference room, 6) six computers with web access, two air-conditioned storage containers, a 15' Boston Whaler, 7) two 4-wheel drive vehicles, and 8) six resident DAR staff: DAR Program Manager, Aquatic Biologist, WFRS Supervisor, Estuarine Surveyor, Fishery Program Assistant and an Office Support Assistant.

4. Hawai'i State and County Facilities. The State and County of Hawai'i has several facilities within the site boundaries that will can be used as sites for education, outreach, research, and natural resource management activities. There is a lei of 15 parks surround the shoreline of the proposed NERRS. These parks include: 1) Honoli'i Beach Park, 2) Mo'oheau Park, 3) Bayfront Beach Park, 4) Wailoa River State Recreation Area, 5) Liliuokalani Park, 6) Coconut Island (Mokuola) Park, 7) Reed's Bay Beach Park, 8) Kuhio Kalaniana'ole Park, 9) Keaukaha Beach Park, 10) Carlsmith Ocean Park Beach, 11) James Kealoha Beach Park, 12) Leleiwi Beach Park, 13) Lihikai (Onekahakaha) Beach Park, 14) Ice Pond, and 15) Richardson Ocean Park. There are also two parks located on the Wailuku River: Boiling Pots and Rainbow Falls. All of these parks include parking, restrooms, and picnic tables. Several of these parks, including Liliuokalani Park, Coconut Island (Mokuola) Park, and Reed's Bay Beach Park are ADA accessible. The Wailoa River State Recreation Area includes the Wailoa Visitors Center, which hosts a variety of exhibitions throughout the year. The County is presently developing the Hilo Bayfront Trails Master Plan, a cohesive system of multi-modal paths, pedestrian sidewalks, dedicated bicycle lanes, shared roads for bicycles and trail amenities spanning the approximately two miles from the Wailuku River and Downtown Hilo to Hilo Harbor. For boating, at the Wailoa River, DLNR DOBOR oversees two boat ramps, vessel washdown facilities, trailer and car parking and 50 moorings. An additional 25 moorings for boats are available at Reed's Bay. DLNR is presently deciding where to install four day-use moorings in Hilo Bay.

5. The Edith Kanaka'ole Foundation. The Edith Kanaka'ole Fountion has three coastal sites which they manage on Kamehameha Schools property. Kamokuna is a coastal area with a natural hau forest and two small ponds. Laehala features a 1000 sqft classroom, a large tidal pool area and a sand beach where turtles and seals can often be observed. Hale o Lono is a traditional fishpond associated with Kalaninuiiamamao an important chief in the history of this island and is the only example of a kuapa fishpond on the east side of the island. A 20x40 tent is set up on site to facilitate group educational activities.

D. Proximity and Accessibility of Site to Researchers, Educators, and Resource Management and Decision Makers. Hilo Bay is easily accessible by road and boats. Much of the coastline is comprised of state and county parks, which are accessible to public by road (*see* C. Facilities, 4. Hawai'i State and County Facilities). The Bay itself is easily accessible for researchers by boat. There is a small boat harbor at the mouth of the Wailoa River and vessels are available through UHH's KMEC program and DAR. There are also 75 moorings available for use.

The State Nā Alahele Trail and Access System manages four trails in the proposed site, one of which is located near the coast and three that are in the upland areas. Trail heads are easily accessible and are no more than 45 minutes from UHH. The 'Onomea Trail is a short trail (~0.5 mi) from the road to the ocean. The three upland trails are the Ka'ūmana Trail (0.6 mi), the Pu'u 'Ō'ō Trail (7.4 mi), and the Pu'u Huluhulu Trail (0.6mi). All upland trails provide access to native landscapes that range from young, barren lava flows to multi-layered forested kīpuka. These trails are also located in seasonal and year-round hunting areas.

E. Controlled Land and Water Access. All shorelines and coastal waters in Hawai'i State are accessible to the public. Specifically, the public has a right of access along the beaches and shorelines below the 'upper reaches of the wash of waves (HRS §115-4, 115-5, Revised 2010). There will be a few locations within the site that may have restricted access due to private ownership (i.e., fishponds). As for lands in the watershed, over 70% is owned by the State and are designated as forest reserves. Access to these lands are open; however, permits are required for hunting and many sites are remote and are only accessible by 4x4 vehicles or hiking.

F. Compatibility with Existing Management Practices and Consumptive and Non Consumptive Uses. Much of the Hilo Bay watershed is state owned forest reserves. These lands are already protected from development and are compatible with NERRS policies. In contrast, Hilo Bay has an active harbor which is expanding to accommodate more vessels. We, therefore, are excluding the port from the reserve. As for water quality, Hilo Bay has been listed as impaired, but many of the parameters it is listed for are from natural sources and not from development (Wiegner et al. 2009, 2012). For example, Hilo Bay is listed for having *Enterococcus* levels exceed state and federal standards. However, studies have shown that these bacteria are not from sewage sources, but from soil runoff (Wiegner et al. 2012). Additionally, soil runoff is high in Hilo because a large portion of the watershed is barren and rainfall is intense and abundant (Wiegner et al. 2009).

G. Compatibility with Adjacent Land Use. The majority of the shoreline is comprised of state and county parks and so its land use is compatible with NERRS. Additionally, much of the Hilo Bay watershed is state owned forest reserves and within the Conservation and Agricultural zoning land use categories. These lands are already protected from development and their designation is compatible with NERRS policies. The waters within Hilo Bay are designated as Ocean Recreation Zones (HAR 13-256-140) and restrict and support multiple ocean uses.

H. Future Development Plans. Lands that can be developed comprise a small percentage of the area within the proposed boundaries of the reserve, specifically those within the Urban and Residential Use designation. Only about 12,000 acres fall within this category. Therefore, most of the lands are protected from future developments. This is aided by fact that the majority of the shoreline is comprised of state and county parks and much of the Hilo Bay watershed is state owned forest reserves or managed by the State, Department of Hawaiian Home Lands.

I. Funding: Potential to Generate Revenue. There are several avenues which can be used to generate revenue for the reserve. One is through extramural grants. Extramural funding just at UHH in the fiscal year 2009 amounted to $20.1 million (*see* Appendix V for details on funded grants related to Hilo Bay). This amount demonstrates UHH's robust commitment to research and scholarship. A second mechanism could be fundraising. One of the reserve staff positions could be charged with fundraising. Fundraising could come from sponsoring events where fees are charged for participants to participate. These events could include cultural performances (hula, music), canoe regattas, and fishing competitions. Funds could also be generated through a 'Friends of Hilo Bay' membership and donating to the site could be possible through the reserve website; many NERRS websites have these platforms. Another mechanism to generate funds could be through the selling of oysters grown in Hilo Bay (once approved); a portion of the profit could be donated to supporting the NERRS. Educational programs could also be offered during school breaks and summer in collaboration with existing programs within the community and the Hilo Bay *Muliwa Hui*.

K. Coastal Resiliency Research. Hilo Bay is well suited for studying climate and coastal change impacts on the area. In Hawaiʻi, the greatest number of deaths from natural hazards have come from tsunamis. Research in Hilo Bay and the surrounding communities has led the nation in the development of coastal resiliency to tsunami hazards (Dudley, 1992). In addition, there are many long-term environmental records from Hilo that can serve as a baseline for assessing climate change. These records include weather, atmospheric carbon dioxide, river discharge, tidal height, and shoreline position. Hilo has one of the longest weather records in the state. The US Weather Bureau established a weather reporting station in Hilo in July 1930, which became part of the National Weather Service in 1950. Since 1950, Hilo Airport has been the site of twice-daily radiosonde atmospheric soundings that record conditions up to about 25 km elevation. And, just 35 miles away, is the historic NOAA Mauna Loa Observatory, with a daily record of carbon dioxide extending back to 1958, as well as more recent time series measurements of many other atmospheric gases and atmospheric properties. USGS records of discharge on the

Wailuku River extend back to 1928, and back to 1911 for Honoli'i River; today, discharge for these two rivers can be monitored in real-time from the USGS website. Sea level rise has been recorded by the Hilo Harbor tide gauge, operated by NOAA, which has a record that extends back to 1927. Coastal erosion can be documented using a collection of aerial photographs of Hilo extending back to the 1950s maintained by UH-Manoa Library.

Change in Hilo has already begun to be detected. Air temperatures are rising (Giambelluca et al. 2008). Precipitation and stream discharge are decreasing (Oki 2004; Chu and Chen 2005). Sea level is rising; sea level at Hilo has risen at an average rate of 1.8 mm/yr since 1946 (Caccamise et al. 2005).

ACRONYMS

ACOE	Army Corps of Engineers
ADA	Americans with Disabilities Act
CTAHR	College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa
CZM	Costal Zone Management
DAR	Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawai'i
DLNR	Department of Land and Natural Resources, State of Hawai'i
DOBOR	Division of Boating and Ocean Recreation, Department of Land and Natural Resources, State of Hawai'i
DOFAW	Division of Forestry and Wildlife, Department of Land and Natural Resources, State of Hawai'i
EKF	Edith Kanakaole Foundation
HCC	Hawai'i Community College
HDOH	Hawaii State Department of Health
HITS	Hawaii Interactive Televion System
KMEC	Kalakaua Marine Education Center
MDC	NOAA Mokupapapa Discovery Center
NERRS	National Estuarine Research Reserve System
NOAA	National Oceanic and Atmospheric Administration
PacIOOS	Pacific Island Ocean Observing System
PACRC	Pacific Aquaculture and Coastal Resources Center
PBARC	Pacific Basin - Agriculture Research Center
PIPES	Pacific Internship Programs for Exploring Science, University of Hawai'i at Hilo
SDAV	Spatial Data Analysis and Visualization Laboratory, University of Hawai'i at Hilo
STEM	Science, Technology, Engineering and Mathematics
TCBES	Tropical Conservation Biology and Environmental Sciences program, University of Hawai'i at Hilo
TMA	Three Mountain Watershed Alliance
TNC	The Nature Conservency
UHH	University of Hawai‘i at Hilo
UHM	University of Hawa‘i at Manoa
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WASC	Western Association of Schools and Colleges
WFRS	Wailoa Fisheries Research Station, Division of Aquatic Resources, State of Hawai‘i

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LIST OF APPENDICES

I. Professional Reports and Peer-Reviewed Publications for Hilo Bay since 2009

II. Undergraduate Senior Theses from Marine Science Department at UHH (related to Hilo Bay)

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APPENDIX I. Professional Reports and Peer-Reviewed Publications for Hilo Bay
A. Reports and Peer-reviewed Publication since 2009

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D. Manuscripts in preparation on Hilo Bay

1. Adolf, J.E, and Jalbert, T.. in prep. Response time of Hilo Bay water quality to storm pulses: analysis of real-time continuous measurements from a water quality buoy.
2. Adolf, J.E., and J. Mooteb. In prep. Spatial and temporal analysis of water quality in Hilo Bay from high-resolution spatial water quality mapping.

APPENDIX II. Undergraduate Senior Theses from Marine Science Department at UHH (related to Hilo Bay)

1. Loretero, J. 2013. Fecal indicator bacteria predictions from water quality parameters in Hilo Bay, Hawaii
2. Smith, K. 2013. *Staphylococcus* distributions and water quality in Liliuokalani Fish Ponds.
3. LeFevre, J. 2013. Phytoplankton and bacteria in SGD plumes in East and West Hawaii.
4. Chandrasakaran, J. 2012. Microbial and chemical indicators of sewage pollution in Waiakea Fishpond and Wailoa River: temporal and spatial analysis.
5. Hess, M. 2012. Impact of stream flow on the decomposition of native and invasive leaf litter in Hawaiian streams.
6. Nestor, V. 2012. Mineralogical and grain size controls of phosphate adsorption
7. Ortiz-Santiago, V. 2012. *Holothuria* (Sea Cucumbers) distribution based on the physical-chemical properties of sediments
8. Guitard, M. 2011. Investigating the past: Exploring the relationship between microfossil assemblage and nutrient concentration
9. Hagiwara, K. 2011. Environmental modulation of lipid accumulation in a Hilo Bay strain of *Chaetoceros socialis*: nitrogen and phosphorus limitations
10. Hernandez, K. M. 2011. Estimation of humpback whale (*Megaptera novaeangliae*) population size in coastal waters of Hilo, Hawaiʻi
11. Posner, E. K. 2011. *In vitro* antioxidant activities of 27 species of Hawaiian macroalgae using the FRAP assay
12. Praast, J. 2011. A linear model of 12-h averages of chlorophyll a in a tropical estuary dependent on time series of assorted water quality factors
13. Seberger, K. R. 2011. Effects of mangrove eradication on water quality at Onekahakaha Beach Park, Hilo, Hawaiʻi
14. Zimmermann, C. P. 2011. Spatial variability and characteristics of surface sediments in Hilo Bay, Hawaiʻi
15. Davis, B. 2010. Nitrate concentrations correlate with algal standing stock
16. Habig, C. A.. 2010. Abundance and antibiotic-resistance of Staphylococcus aureus in coastal waters of east Hawaiʻi
17. Mooteb, J. 2010. Water quality monitoring during tidal phases of Hilo Bay, Hawaiʻi using GIS
18. Silver, D. 2010. Spatial and temporal variation of phytoplankton nutrient limitation in Hilo Bay
19. Strohl, D. 2010. Effects of the invasive alga *Gracilaria salicornia* on molluscan species abundance, richness, and diversity in east Hawaiʻi
20. Walker, J. 2010. Evaluation of photoacclimation of emergent intertidal macroalgae using in situ PAM fluorometry and in vivo absorption spectroscopy
21. Wysock, G. 2010. Diel horizontal distribution of phytoplankton from two stations within Hilo Bay estuary
22. Zellner, N. 2010. Site fidelity and fibropapillomatosis tumor incidence in green sea turtles (*Chelonia mydas*) on Hawaiʻi Island
23. Kelley, C. 2008. Carbon dioxide fluxes in Hilo Bay, Hawaiʻi, during baseline and storm flow conditions
24. Seferovic, N. 2008. Nutrient and bacterial indicators of potential sewage contaminated groundwater in Hilo Bay, Hawaiʻi

APPENDIX III. Support Letters

A. Edith Kanakaʻole Foundation
B. Three Mountain Alliance
C. Mauna Kea Watershed Alliance
D. Department of Aquatic Resources
E. UHH Spatial Data Analysis and Visualization Laboratory
F. UHH Analytical Laboratory

Liko ka liko i ka ua.

Edith Kanaka'ole Foundation

To: Whom it may concern

August 14, 2013

From: Kalahoohie Mossman
Site Manager
Edith Kanakaole Foundation

On behalf of the Edith Kanaka'ole Foundation, I would like to express our support for the inclusion of the Hilo bay area as a NERRS site and acknowledge our commitment to the success of the program if selected. The Edith Kanaka'ole Foundation continues to be involved in the Hawaiian cultural practice of managing our natural and cultural resources, which includes a stretch of coastline within the proposed project area, as well as the only kuapa fishpond on the east side of the island of Hawaii. We are particularly interested in this project as it connects our coastal resources to the source of the water providing an educational opportunity to encompass a more holistic view of our environment and one that is more in line with the teachings of our ancestors. We are equally excited in the collaboration of the various stakeholders in this project and feel that the outcome will not only benefit the resource but our greater community as well. Thank you for your time and consideration.

Sincerely,

Kalahoohie Mossman

THREE MOUNTAIN ALLIANCE

MEMBERS
HAWAI'I DEPT. OF LAND & NATURAL RESOURCES
USGS BIOLOGICAL RESOURCES DIVISION
KAMEHAMEHA SCHOOLS
USDA FOREST SERVICE
NATURAL RESOURCES CONSERVATION SERVICE
HAWAI'I DEPT. OF PUBLIC SAFETY
HAWAI'I VOLCANOES NATIONAL PARK
US FISH AND WILDLIFE SERVICE
THE NATURE CONSERVANCY OF HAWAI'I

PO BOX 52 · HAWAI'I NATIONAL PARK, HI · 96718 · PH 808.985.6197 · FX 808.985.6029

15 August 2013

To Whom It May Concern:

The Three Mountain Alliance (TMA) watershed partnership is in full support of the Hilo Bay designation as a National Estuarine Research Reserve System (NERRS) site. Founded in 1994, the TMA is a voluntary alliance of federal and state agencies and private landowners who collectively own and manage over one million acres across the three volcanoes of Mauna Loa, Hualālai, and Kīlauea on Hawai'i Island. Part of the Hilo Bay watershed falls within the TMA Management area. The overall management goal of the TMA is to sustain the multiple ecosystem benefits provided by the three mountains by responsibly managing its watershed areas, native habitats and species, historical, cultural, and socio-economic resources for all who benefit from the continued health of the three mountains. Since 1999, The TMAs environmental education program, 'Imi Pono no ka 'Āina ('Imi Pono) has provided conservation-themed programs for students and teachers, led community service trips, and participated at community events across the Island. We strongly believe in the need to build capacity for community/place-based stewardship of our natural resources and the NERRS designation would be a novel way to address this need.

The TMA's management, outreach and education goals align well with the NERRS mission to promote the stewardship of natural resources through innovative research, education, and training using a place-based system of protected areas. The TMA has a long history of coordinating landscape scale ecosystem conservation and management projects through collaborations and partnerships and we look forward to helping facilitate the projects and programs of the Hilo Bay NERRS's actions in this area. Additionally, 'Imi Pono has a long and successful record of working with schools and students, offering engaging, site-based learning experiences which integrate Hawaiian cultural knowledge and practices with natural history and resource management. 'Imi Pono is able to support the NERRS in the development and implementation of education and outreach programs, curriculum development, and to provide educational resources and supplies that will empower students and community members to explore, learn, and become active participants in protecting Hawai'i's natural resources.

We believe the Hilo Bay watershed is an excellent site for the NERRS designation. The Hilo Bay watershed has the highest ground water recharge on the Island, an invaluable resource for all. TMA is committed to watershed protection and works to address present and future threats to the watershed including invasive species, deforestation, disease and fire. The education and research programs that already exist in the Hilo Bay watershed provide a strong foundation and catalyst for the development of effective stewardship projects leading to improved watershed health, and consequently improved community health. We believe strongly that the landscape-scale, watershed approach to the Hilo Bay NERRS is the most effective way to protect and manage our natural resources for generations to come.

Please do not hesitate to contact me with any questions that you might have.

Sincerely,

Colleen Cole
Coordinator, Three Mountain Alliance

MKWA
Mauna Kea
Watershed Alliance

August 15, 2013

Site Selection Committee
National Estuarine Research Reserve System

RE: Hilo National Estuarine Research Reserve System designation

Aloha kākou,

I am writing to express our support for the National Estuarine Research Reserve System designation for the Hilo Watershed, Hawai'i. The Mauna Kea Watershed Alliance (MKWA) have four partners lands in the *mauka* (towards the mountains) watersheds including the Hakalau Forest National Wildlife Refuge, Department of Land and Natural Resources, Kamehameha Schools, and the Department of Hawaiian Home Lands. The MKWA boundaries spans over 500,000 acres across the Mauna Kea landscape of which several landholders including Federal and State of Hawaii agencies, Non-Profits, Private and Ranch lands have signed our Memorandum of Understanding. Our shared vision is to protect and enhance watershed ecosystems, biodiversity and resources through responsible management, while promoting economic sustainability and providing recreational, subsistence, educational and research opportunities.

The needs for protection and restoration of native ecosystems to support ecological function are tremendous. The Hawaiian Islands have extraordinary cultural and bio-diversity and Mauna Kea encompasses the full range of Pacific forest values for products, ecosystem services, and cultural practices. The threats to island ecosystems are serious and accelerating, largely the result of biological invasion by exotic plants and feral animals. However, the MKWA is committed to long-term sustainable watershed management of these lands. This proposal represents a critical step toward the integration of land management at landscape scales and we stand poised to include partnership resources to increase the effectiveness and timeliness of management here on Mauna Kea.

Please consider the Mauna Kea Watershed Alliance a strong advocate and partner for the proposed work.

Mahalo,

Cheyenne Hiapo Perry
Mauna Kea Watershed Alliance Coordinator
160 Baker Avenue, Hilo, HI 96720
(808) 937-5170

NEIL ABERCROMBIE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

DIVISION OF AQUATIC RESOURCES
1151 Punchbowl Street, Room 330
Hilo, Hawaii 96813

15 August 2013

Dr. Tracy Wiegner
University of Hawaii – Hilo
Marine Science Department
Hilo, Hawaii

Re: Support for Designation of Hilo Bay Estuary as NERRS site

Aloha members of Hilo Bay estuary NERRS working group,

On behalf of the Division of Aquatic Resources/Department of Land and Natural Resources, we strongly support your proposal for the designation of Hilo Bay estuary as a site within the National Estuarine Reserve Research System network.

Operating the Wailoa Fisheries Research Station within the greater Hilo Bay estuary has given Division of Aquatic Resources' staff firsthand experience with this gem of a Hawaiian estuary. With multiple freshwater sources discharging into Hilo Bay and interacting with the incoming Pacific Ocean, we have long recognized the significance of this estuarine resource for the State of Hawaii. As such, Hilo Bay's diverse habitats, aquatic productivity, changing land use, fisheries landings and fisheries stocks have been careful monitored for over 20 years by DAR. As we expand our research efforts to understand estuarine resources across the Main Hawaiian Islands, Hilo Bay remains a focal point and one of our key research sites.

Should Hilo Bay estuary become a site within the National Estuarine Reserve Research System network, DAR staff can participate in research on coastal zone management, fisheries stocks and other important aspects of this program. Specifically, we offer both a local perspective (Hilo Bay) and an archipelago wide view of Hawaiian estuaries.

If further information is needed, please contact me at: kimberly.a.peyton@hawaii.gov or 808-222-7533.

Sincerely yours,

Kimberly A. Peyton, Ph.D.
Research Scientist

SDAV
Spatial Data Analysis and Visualization Labs
HILO

University of Hawai'i at Hilo
200 W Kawili St., Rm. K273A
Hilo, HI 96720-4091
808.933.3190

August 15, 2013

To: Site Selection Committee Members
National Estuarine Research Reserve System

Fr: Lisa Canale
Lab Manager
University of Hawai'i at Hilo Spatial Data Analysis and Visualization Labs

RE: National Estuarine Research Reserve – Hilo Bay site

I am writing in my capacity as the manager of the University of Hawai'i (UH) at Hilo Spatial Data Analysis and Visualization (SDAV) Labs to enthusiastically support Hilo Bay being designated as a National Estuarine Research Reserve System (NERRS) site. In support this endeavor our facility would be able to potentially assist with many geospatial activities such as:

- Providing geospatial training for NERRS staff in our SDAV classroom for training
- Providing access to the SDAV research lab server complex, workstations, and geospatial software for participating researchers ,
- Providing geo-website hosting,
- Providing SDAV personnel and student interns to assist with geospatial analysis, and
- Providing the use of geospatial equipment for in-field data collection.

Since 2001 the SDAV labs have specialized in advancing Hawai'i-based geospatial curriculum and scientific research through adopting and utilizing the latest technology for spatial and temporal analysis and visualization. Our approach to curriculum support and research accentuates multidisciplinary methodology; we practice and encourage cooperation and sharing of knowledge within the educational system and with the private and public sectors. Hilo Bay as a NERRS site has great potential for acquiring knowledge for both academic and practical use in Hawai'i. The designation will strengthen the ability of UH Hilo to develop effective independent scientists and other learners.

We look forward to collaboration with the Hilo Bay NERRS site personnel and the Hilo Bay NERRS site projects.

Sincerely,

Lisa Canale

Lisa Canale

UNIVERSITY
OF HAWAI'I
HILO

Site Selection Committee Members
National Estuarine Research Reserve System

August 12, 2013

To Whom It May Concern:

We at the University of Hawaii at Hilo's (UHH) Analytical Laboratory are thrilled at the prospect of Hilo Bay being designated a National Estuarine Research Reserve System site. Our laboratory would be able to assist the reserve staff with monitoring, education, and workforce development efforts. The UHH's Analytical Laboratory was established in 2003 and it includes analytical chemistry instrumentation for water quality and biological analyses (i.e., water, soil, bacteria, plant, and animal tissue). Space, equipment, services, and training would be available to students (K-12, undergraduates, and graduates) faculty, interns, NERRS support staff, and researchers to use for programs, projects, and long-term monitoring (see attached list of equipment and services). Laboratory staff would be available to help train the reserve personnel with sampling protocols, preparation, and methods. We look forward to the possibility of working in a designated NERRS site.

Sincerely,

Tara Holitzki
Analytical Lab Manager

Marine Science
200 W. Kawili St.
Hilo, HI 96720-4091
Phone: (808) 933-3168
Fax: (808) 933-0423
analytic@hawaii.edu

UHH Analytical Lab Services and Equipment

Services

Nutrients for Water Samples (Lachat Quickchem 8500, Series 2)

- Nitrate+Nitrite, Orthophosphate, Silica, Ammonia, Nitrite Only, Total Phosphorus

Nutrients for Extracts (Technicon Auto-Analyzer)

- Nitrate+Nitrite, Orthophosphate, and Ammonia

Total Organic Carbon/Total Nitrogen for Water Samples (Shimadzu TOC/TN)

- Total Carbon (TC), Total Inorganic Carbon (TIC), Total Organic Carbon (TOC), and, Total Nitrogen (TN)

Carbon/Nitrogen for Solid Samples (Costech Elemental Analyzer)

- Total Carbon, Total Nitrogen, Total Hydrogen, and GF/F filters

Stable Isotope Analysis (Thermo Delta V IRMS)

- Carbon Ratio (13C/12C) and Nitrogen Ratio (15N/14N)

Elemental Analysis (ICP-OES)

- Elements upon request

Equipment

Balances, muffle furnaces, drying ovens, fluorometers, spectrophotometers, freezers, centrifuges, acid washing station, vacuum pumps, centrifuges, microscopes, grinding mills, and Wig-L-Bug (isotope sample prep).

APPENDIX VI. Master's Theses from TCBES program at UHH (related to Hilo Bay)

1 .Weisz, C. 2012- present. Microbial source tracking and prediction in Hilo Bay: a spatial and temporal analysis.
2. Carlson, K. 2011-present. A comparison of bacterial growth efficiency in nearshore waters with submarine groundwater discharge on the leeward and windward coasts of Hawaii Island.
3. DeBenedet, R. 2011. B-WET Hawaiian ahupuaa : bay and watershed education training program August 2010 - May 2010 Connections Public Charter School. University of Hawai'i at Hilo.
4. Holitzki, T. 2010. Impacts of invasive poeciliid fish on Hawaiian stream ecosystems.
5. Atwood, T.B. 2009. Effects of hydrological forcing on the structure of a tropical estuarine food web.
6. Mead, L.M. 2008. Surface water metabolism in a tropical estuary, Hilo Bay, Hawaii, USA, during storm and non-storm conditions.
7. Tubal, R. L. 2007. Comparison of dissolved organic carbon bioavailability from native and invasive vegetation along the Wailuku River, Hawaii.

APPENDIX V. Funded Research

A. Current Funded Research Projects

1. University of Hawaii Sea Grant College Program. Microbial pollution source tracking and prediction in Hilo Bay: a spatial and temporal analysis. Tracy Wiegner (PI), Jason Adolf, Jonathan Awaya, and Stephanie Molloy. $59,710 + $61,064 (graduate assistant). 2012-2014.
2. NOAA Coastal Storms Program. Installation of coastal radar arrays to monitor ocean currents and improve community storm preparedness: Hilo Bay, Hawaiʻi Island' Jason E. Adolf (PI). Steven Colbert, Henry Carson, Pierre Flament. $180,000.
3. Integrated Ocean Observing System Program, NOS, NOAA, Department of Commerce, through the National Oceanographic Partnerships Program. Pacific Island Ocean Observing System (PacIOOS). Brain Taylor (PI), Tracy Wiegner (participant with Jason Adolf for Hilo Bay Buoy). $20,000,000 ($90,000 for Hilo Bay buoy) (2011-2016).

B. Previously Funded Research Projects Since 2004

1. UHH EPSCoR Research Enhancement Activities Program. 2008. Phytoplankton ecology of Hilo Bay, Hawaii: real time continuous monitoring to detect changes in phytoplankton biomass and community composition due to natural and anthropogenic factors. Jason Adolf (PI), Tracy Wiegner, Jene Michaud, and Jason Turner. $25,000
2. NSF EPSCoR RII2 UHH Ecology Area. 2007. Tracy Wiegner (Leader for ecology focal area). $669,003 (2006-2009)
3. County of Hawai`i, Department of Public Works. 2006. Hilo Bay water quality study. Tracy Wiegner (PI). $66,000
4. B-WET Program (NOAA). 2006. RELATE: River environments landuse and ahupua`a technologies. Sonia Juvik (PI), Cynthia Phillips, and Tracy Wiegner (collaborator). $90,000
5. UHH EPSCoR Ecology Area Plan for Project Organization. 2006. Ecohydrology in Hawai`i: Linking volume and quality of water flow through soil, streams, vegetation, and atmosphere, from mountain to coastal discharge. Lawren Sack (Co-PI), Tracy Wiegner (Co-PI), Ka'eo Duarte, Jason Turner. $200,000 (2006-2008)
6. UHH EPSCoR Research Enhancement Activities Program. 2006. Terrestrial impacts on estuarine nutrient cycling. Jason Turner (PI), Tracy Wiegner, James Beets, Jene Michaud, C. Ray, and Celia Smith. $23,775.
7. University of Hawai`i Sea Grant College Program (NOAA). 2005. Bioavailability of natural and anthropogenic dissolved and particulate organic matter from Hilo Bay ahupua'a. Tracy Wiegner (PI) and Richard MacKenzie. $70,838 direct, $36,114 graduate student stipend.
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