CHAPTER 15

People, Land, and the Reefs of South Moloka‘i

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Waters along the southern shore of Moloka‘i are frequently turbid, a result of large quantities of suspended sediment. The most dominant factor contributing to this condition is the legacy of several hundred years of human activities on the island. We have examined archaeological and historical evidence to understand the impact that evolving societies had on Moloka‘i, from the watersheds to the reefs. This chapter takes a look at activities that have influenced the rate, volume, and extent of soil erosion and deposition and the overall changes to the south-facing slopes and coast. These activities include land settlement and clearing, construction of shoreline fishponds, interisland war, livestock introduction, farming practices, and the effects of fire and feral grazers.

Impacts of Human Occupation on Moloka‘i

Early Human Activities

The first people arrived on Moloka‘i 1,400 years ago and through their settlement began to alter the surface of the land. For much of early Hawaiian history, the southeastern coastal plain or kona district (fig. 1) carried most of the population (de Loach, 1975). Hawaiians eventually settled other parts of the island, including the Ho‘olehua Saddle (the area between the east and west volcanoes), the upper reaches of the south-facing slopes, and much of the south-central coastal plain.

Although no written records were kept during the early period of human habitation, there are indicators of how settlement proceeded. We can combine knowledge of the social organization in the Pacific Islands where the settlers lived before traveling to Moloka‘i, and archaeological evidence found on Moloka‘i (Weisler and Kirch, 1985), to provide a sense of conditions and processes during the time of the early settlers.

The earliest Polynesian voyagers to settle on Moloka‘i arrived around the year 600 C.E.[3] in the area now known as Hālawa, at the eastern tip of the island. As settlers began to explore the island, they discovered the gentler slopes and broad reef areas to the south and west. Here, long-term stream erosion had produced low-lying coastal plains and alluvial fans mantled with loose, rich soil that was easy to cultivate. The resources of the adjacent reef were also valued, and settlements gradually spread westward along the south coast.

The early Hawaiian settlers brought with them their customs and traditions, including a system of land use and organization still used today in many Pacific island nations. In this feudal scheme, an ali‘i (chief) assigned the use of an ahupua‘a (a portion of the land) to a small group or family unit (fig. 2). The ahupua‘a commonly included a valley and the adjoining hillsides, running from the top of the watershed to the nearshore waters and the adjacent reef. Each ahupua‘a provided access to everything the people might need: water from a stream or springs, wood from the higher elevations, forage on the lower slopes, land along the coast for cultivating, and access to the full resources of the reef flats and shallows.

Early clearing and farming activities centered on planting traditional staples the settlers brought from their previous homes in Polynesia: taro and sweet potatoes. They also introduced many other plants: sugar cane, bananas, coconut, breadfruit, ginger, pepper, and mulberry (Bryan, 1954). Little evidence of formal villages has been found from this very early period, only signs of occasional small huts and perhaps a community heiau (altar or sacred site). Although the clearing process may have included some burning, with few people and a broadly scattered population, the impact of the people on the land was likely minimal for the first four centuries of human habitation.

Building on the Edge of the Sea

During the next 400 years, starting about 1,000 C.E., changes in the evolving society began to leave visible changes on the landscape. Early in this period the ali‘i nui (high chiefs) of the larger Hawaiian islands seem to have ignored the small, lightly populated island of Moloka‘i as they battled over larger prizes elsewhere in the islands. This was the period when many stone works were completed on Moloka‘i, including terraces on the hillslopes to keep soil and water in place for growing taro and other

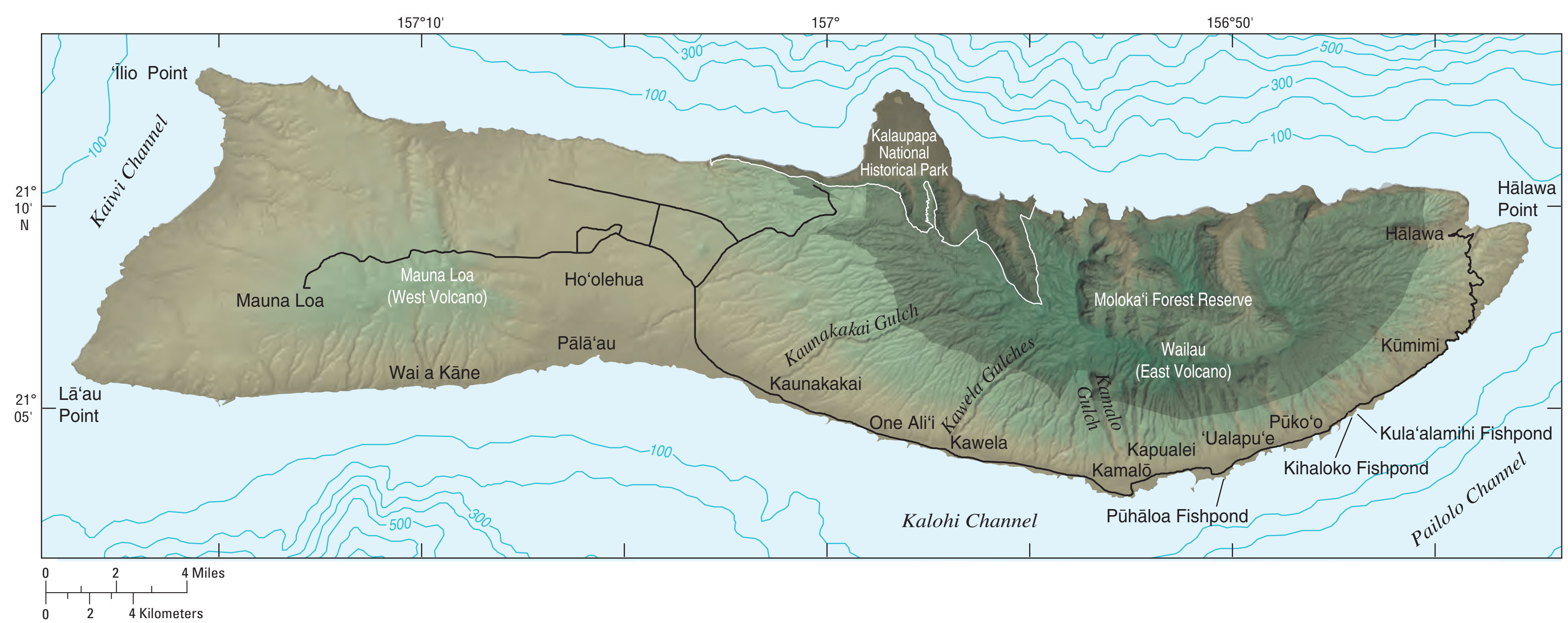

Figure 1. Map of Moloka‘i, showing locations mentioned in the text. Bathymetric contour interval, 100 m.

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[3]C.E. (Common Era) and B.C.E. (Before Common Era) are often used by social scientists to refer to what others call A.D. (Anno Domini or in the year of the Lord) and B.C. (before Christ), but without religious connotation.

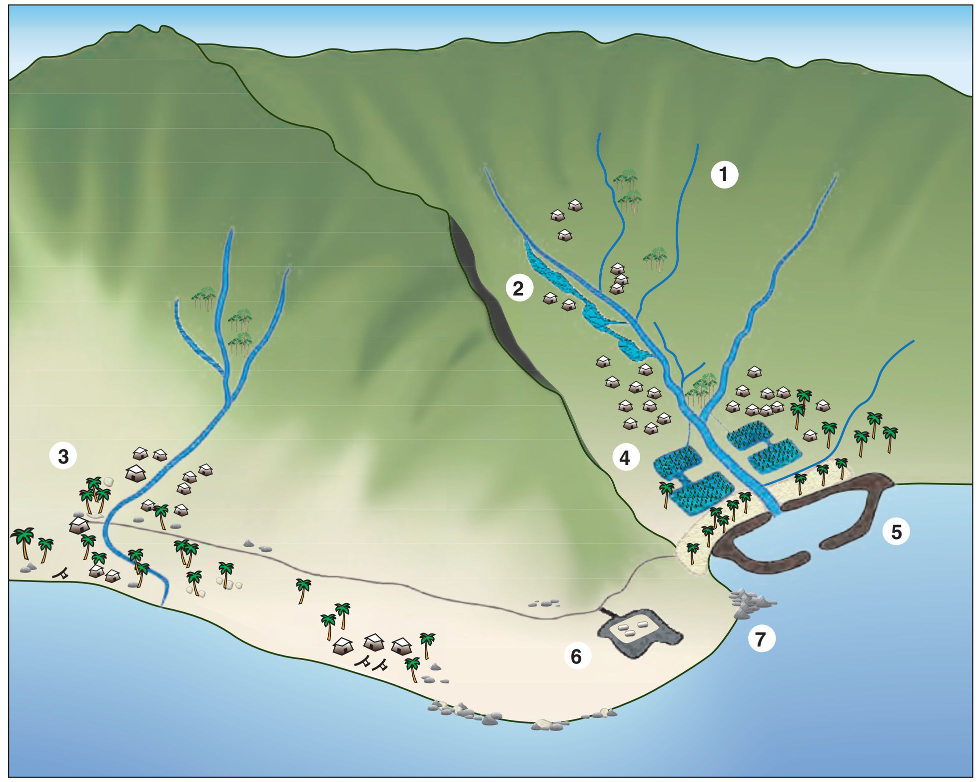

Figure 2. Drawing of an ahupua‘a (modified from HawaiiHistory.org, http://www.hawaiihistory.org, last accessed April 29, 2008). The ahupua‘a is based on a traditional Polynesian style of land management that divides an island into segments running from the mountainous interior to the edge of the reef, cutting through all the ecological zones (Weisler and Kirch, 1985, p. 129). Each ahupua‘a provides for all the needs of a family or small group of people. 1, Streams carry mountain rainwater from ridges down steep slopes. 2, Stream water is diverted in narrow taro fields in the upper valley. 3, Coconut trees provide food and drink. 4, Broader taro fields fill the wider valley mouth. 5, Coastal fishpond is open to the sea. 6, Fishing village heiau (sacred altar). 7, Rock marker at ahupua‘a boundary.

crops (de Loach, 1975). More than 50 fishponds for raising fish were built on reef flats along the south coast, most of them completed by the early 15th century.

Although other islands also had fishponds, Moloka‘i had perhaps the greatest concentration, in large part because of the extensive shallow reef flat along the south shore (fig. 3). Some fishponds occupied several hundred acres, with enclosing walls averaging 1.5 m (5 feet) high and 3 m (10 feet) thick (Kepler and Kepler, 1991). Most fishponds were relatively shallow (1 m or 3 feet) but some were as deep as 10 m (33 feet). The presence of fishponds on the reef flat altered the natural pathways for water and sediment. Sediment flushed to the coast during rainy periods was deposited in the ponds, requiring constant tending to prevent them from filling and becoming unusable for raising fish (as in fig. 3*A*) for the island ali‘i.

A Time of Extremes—Quiet Prosperity or Invasion

During the time between the first fishponds and the arrival of outsiders from Europe and America in the late 1700s, the people of Moloka‘i developed a comfortable level of prosperity. Crops were plentiful and the ponds filled with fish. However, in this same period the ali‘i nui of the larger islands fought many battles. Because it was located between the warring factions of Hawai‘i, Maui, and O‘ahu, Moloka‘i served as both a refuge and a source of provisions. The island was conquered, perhaps many times, by ali‘i nui of other islands. One of the conquering ali‘i nui was Kapi‘iohokalani, who ruled O‘ahu in the 1730s. According to de Loach (1975, p. 27), “Kapi‘iohokalani invaded Moloka‘i somewhere around 1736. He attacked with a large force, and his army broke down sea walls and destroyed many fishponds.” Conflict among the ali‘i nui continued for at least 30 years after the outsiders came. Then, in the late 1700s, Kamehameha I used Western firearms and small, fast boats to conquer his opponents and declare his power over all the islands. It is said of his taking of Moloka‘i that, “Kamehameha’s descent upon it had desolated the country” (Menzies, 1920, p. 118). Robert Louis Stevenson, visiting Moloka‘i several years after the battles ended, painted a vivid word picture of the devastation: “...upon this island a battle was fought in which it has been computed that thousands were engaged; and he who made the computation, though

Figure 3. Aerial photographs of fishponds on the southeastern coast of Moloka‘i. Constructed in the 11th through 15th centuries, these fishponds have great cultural and historical value to the people of Hawai‘i. *A*, Pūhāloa fishpond between Kalaeloa and ‘Ualapu‘e, showing the large amount of sediment infilling that has occurred here. As vegetation takes hold, trapping of sediment and infilling rates increase. *B*, Kihaloko (left) and Kula‘alamihi fishponds east of Pūko‘o link together to form a nearly continuous armored shoreline. This photograph shows the lower part of several ahupua‘a as well. *C*, Submerged remains of fishpond walls are shown by arrows.

Susan Cochran, USGS

Figure 4. A historical lua moku ‘iliahi, or sandalwood measuring pit (outlined by dashed line), on the Moloka‘i high slopes. Approximately 23 m (75 ft) long, the pit was dug in a size and shape that mimicked the size of the hold of sailing ships that carried the sandalwood back to New England. Sandalwood was cut and stacked in the pits, and then hauled to ships waiting at anchor.

he lived long after, has seen and counted, when the wind blew aside the sands, the multitude of bones and skulls" (Stevenson, 1973, p. 75).

A Faster Rate of Change

While the ali‘i nui were battling for power, Europeans, beginning with Cook and Vancouver in the 1770s, entered the islands, bringing with them irrevocable change to the people and the habitat. Along with firearms and fast ships, the explorers from Europe and America introduced grazing animals and commercial farming. Both ideas caused rapid changes to the hillsides and reefs of Moloka‘i over the next 100 years. Animals were initially introduced by explorers to be used as a food source on their return. The ali‘i quickly realized that they could also raise animals to use and to sell. Goats, swine, sheep, cattle, and horses were introduced and began to thrive on Moloka‘i by the end of the 1800s. In 1870, Kamehameha V sent his small herd of deer to Moloka‘i, where they also flourished (Judd, 1936).

Hawaiian vegetation evolved without native grazing animals. Trees, ferns, and bushes developed soft bark, tender greenery, and lacked thorns—and were therefore defenseless against grazing animals (Bryan, 1954). As the number of animals increased on Moloka‘i, the distribution of native vegetation was altered, particularly in the cooler upper reaches of the island's watersheds. Goats, sheep, and cattle are known to graze heavily on dense vegetation wherever it is available, leading to increased susceptibility of exposed areas to the effects of wind and rain. This is consistent with conditions noted on the higher slopes of Moloka‘i. Increasing amounts of soil were transported and deposited on the low southern slopes and, eventually, on the reef flat. The loss of soil in the uplands led to further habitat destruction and changes in local microclimates. Without the heavy vegetation to capture the moist, rising winds, rainfall decreased in upland areas. Many springs dried up (Kepler and Kepler, 1991), and people abandoned efforts to raise grazing animals. Pigs and goats turned feral (wild) and migrated to the rugged, hard-to-reach areas of the high slopes, where they, along with deer, fed on small saplings and grasses and dug for roots, further contributing to soil loss. As the animal population grew, the human population declined. From early estimates of 10,500 people on Moloka‘i in 1779 (Summers, 1971), the population dropped to 2,307 by 1896 (Bottenfield, 1958), leaving fewer people to hunt the animals and keep them in check.

Two other early activities adversely affected the south slopes of Moloka‘i: the sandalwood trade and plantation-style agriculture. Early in the 1800s, sandalwood—highly prized in the Orient—became a great trade commodity. Moloka‘i stands of this tree were smaller than those found on other islands but considered large enough to warrant logging, as evidenced by the digging of at least one ‘sandalwood pit' (a hole in the ground the size of a ship's hold, used for measuring the amount of wood needed to provide a full cargo; see fig. 4). To support this venture, the ali‘i directed the men to leave their fields and focus on harvesting the trees (Bottenfield, 1958). According to Cooke (1949, p. 61), "It is said that the extinction of sandalwood was caused by the natives destroying young sandalwood plants. They did not wish their descendants to undergo the hardship of obtaining the sandalwood from the cold, wet mountains and having to transport it to the shore." The removal of sandalwood and exposure of soil

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Figure 5. Characteristic severe erosion on west Moloka‘i, just west of the Ho‘olehua Saddle. The red-brown soils are eroded during heavy rainfall and transported to the coast through gulleys and by overland flow. This type of erosion is typical of areas that have had the forest canopy removed.

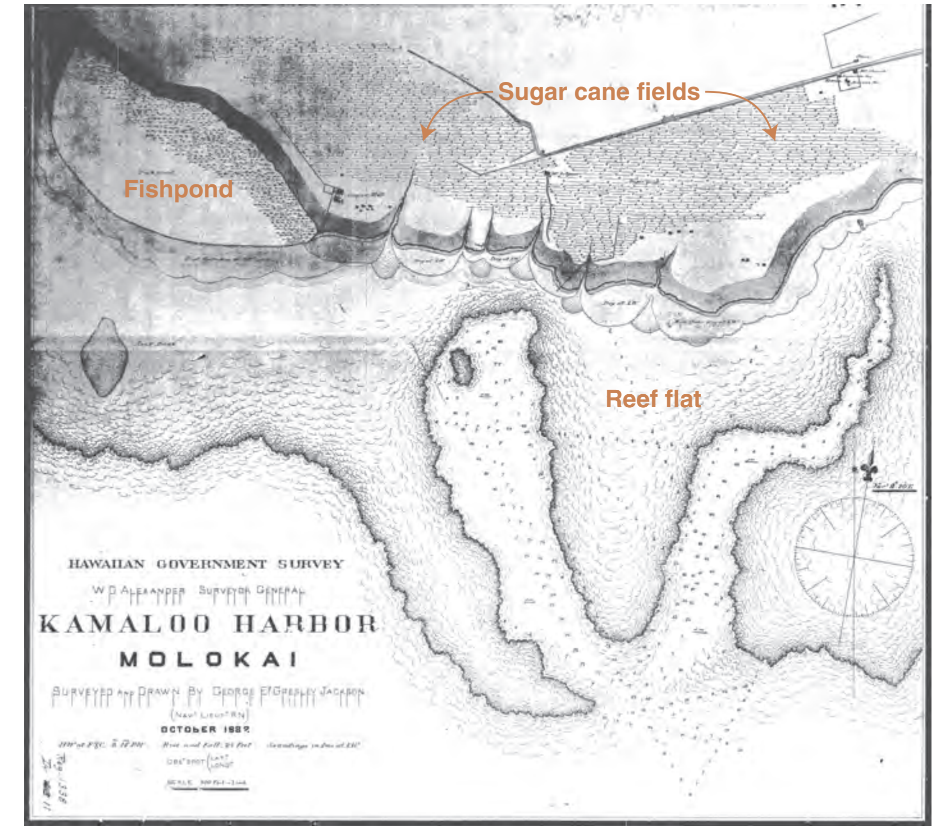

Figure 6. Map of Kamalo‘o (as it was called then; today it is Kamalō) showing the shape of the coast in 1882 and the sugar cane fields near the shoreline (from Jackson, 1882). Sediment derived from the erosion of the exposed sugar cane fields was transported to the coast, resulting in a change in shape of the shoreline.

for agriculture, especially in the area of Ho‘olehua Saddle, contributed to additional erosion.

Soil loss likely accelerated in the mid 1800s when cattle ranching intensified on the upper reaches of Ho‘olehua Saddle. Low-quality cattle, sold for hides and tallow, were raised in large numbers and driven south to Pālā‘au for shipment. The damage done by the trampling of driven herds added to the damage done by grazing (fig. 5). By the end of the 1800s, sediment was deposited in the central lowland plain at a rate of one foot (30 cm) every six years (Cooke, 1949; D'Iorio, this vol., chap. 16).

Plantation monoculture was also introduced during the 1800s. Sugar cane was one of the first such crops and was grown in several areas along the southeastern coastal plain (Jackson, 1882; fig. 6), "but the holdings were abandoned when it was found that the artesian water being used was too salty" (Keesing, 1936, p. 27). This system left lasting problems. Between the destruction of native vegetation necessary for plantations and the insects and diseases associated with the introduced species, even taro and some vegetables could no longer be grown in certain areas. Changes in land-use patterns were visible long after the sugar plantations disappeared (Gast, 1982). Thus

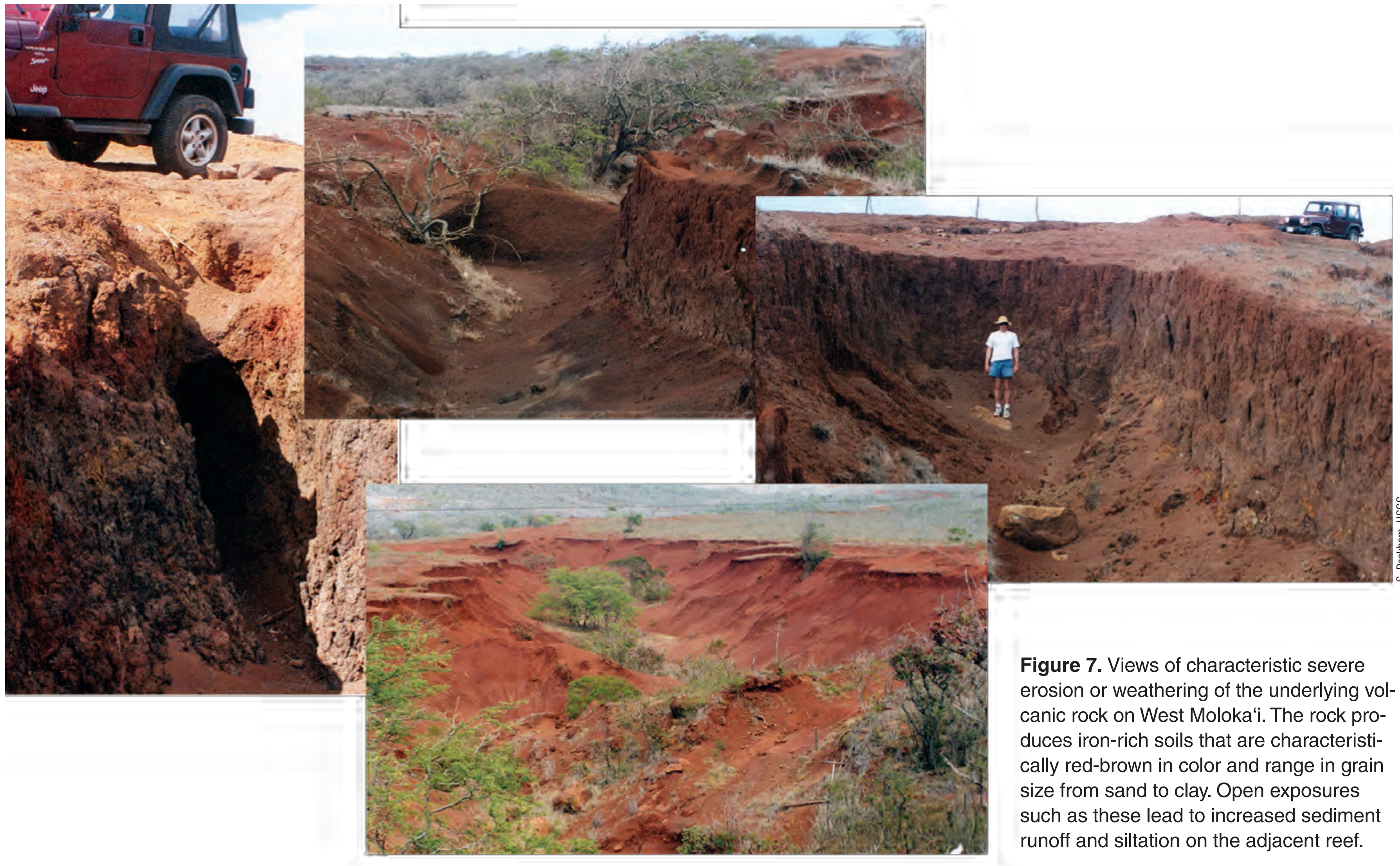

Figure 7. Views of characteristic severe erosion or weathering of the underlying volcanic rock on West Moloka‘i. The rock produces iron-rich soils that are characteristically red-brown in color and range in grain size from sand to clay. Open exposures such as these lead to increased sediment runoff and siltation on the adjacent reef.

the clearing necessary for such monoculture heightened the susceptibility of the soils to erosion in the lower coastal areas as well.

Modern Actions, For Better or Worse

By the twentieth century, the damage to the landscape and soil cover (fig. 7) caused by ranching and sugar cane farming had become evident, and some corrective measures were introduced. At the same time, some damaging activities continued and new ones were introduced. Repairing centuries of damage has proved challenging:

- Between 1898 and 1905, Moloka‘i Ranch, the largest landholder on the island, shifted from open country grazing to a paddock system in an effort to limit the impact of cattle on the vegetation in selected areas (Henke, 1929). This measure was only marginally successful, and erosion caused by destruction of overlying vegetation can still be seen today (fig. 5).
- In 1902, mangroves (*Rhizophora mangle*) were introduced by the American Sugar Company in an effort to stabilize the coastal mudflats at Pālā‘au in south-central Moloka‘i and hold back the soil washed down by heavy rains into the sea (Allen, 1998, p. 62).
- By 1907, the sheep population on Moloka‘i reached 17,000 animals, grazing mostly on the grasses of the Ho‘olehua Saddle and denuding large areas of pasture. Sheep-raising was finally discontinued “only because of reduced grazing areas and a poor wool market” (Henke, 1929, p. 18).
- In 1912, the Moloka‘i Forest Reserve was created, covering a large part of the eastern uplands of the island as a cooperative effort of government and local landowners. Fencing and volunteer restraint were used to give the upper slopes of the south-draining watersheds a chance to recover from the livestock damage. Effectiveness of conservation and remediation efforts varied with the dedication of those involved.
- In the 1920s, much of the Ho‘olehua Saddle was set aside as Hawaiian Homestead lands and was opened to farming. Clearing the land for farming made the loose, red soil more susceptible to the eroding effect of the prevailing northeast trade winds, while the planting of windbreaks was only marginally successful in mitigating the damage. Ironically, the homesteaders found it more lucrative to lease their parcels to the big pineapple producers than to farm them individually, leading to the additional environmental damage associated with extensive monoculture.
- By 1930, much of the island was devoted to either pineapple cultivation or to grazing. Both activities continued to alter the land of the Ho‘olehua Saddle and the coastal plain. As Handy (1931) noted, most fishponds by this time had been abandoned and were filled with mud.
- In 1934, the modern pier at Kaunakakai was built (Kepler and Kepler, 1991). This large-rock structure had a base substantial enough to carry a two-lane road, and it supported an expanded landing facility. Its position, jutting as it did at least 800 m (nearly 0.5 mi) south across the reef flat along the eastern edge of a natural channel in the reef, disrupted the along-shore flow of water.
- In 1948, the Moloka‘i-Lāna‘i Soil Conservation District was formed by the U.S. Department of Agriculture to help local residents reverse the environmental damage and improve the management of their lands. A Moloka‘i field office was established to disseminate information and assistance to landowners, farmers, and tenants to promote their conservation efforts by a broad variety of means (S. Cox, oral commun., 2000).
- The Nature Conservancy established an office on Moloka‘i in 1983 (E. Misaki, oral commun., 2000), adding their efforts to those of others attempting to reverse centuries of environmental damage and halt its progress. Since that time they have been working with local hunters and State and Federal agencies to try to control the feral goat population.

The Late Twentieth Century

Although agriculture has been the main land use influencing erosion rates on Moloka‘i, increased construction and road building have added to the runoff of water and sediment. Road cuts expose layers of loose soil that

National Oceanic and Atmospheric Administration, 1993

Bruce Richmond, USGS

Figure 8. Aerial photographs of the reef flat east of Kamalō showing impact of coastal development. Dredging of coastal materials and reef deposits produces high levels of turbidity and sedimentation locally. These two projects generated tons of sediment that washed across the reef, and according to local accounts, killed acres of corals. *A*, 1993 aerial photograph shows an irregular pit in the reef flat (straight-edged area of deeper, dark blue water) that was the site of excavation in the 1950s for a proposed marina. *B*, Oblique 1998 photograph of Pūko‘o Harbor is an example of shoreline modification. Construction of the harbor resulted in a large volume of fine sediment being released onto adjacent coral covered areas.

is easily eroded and transported to the coast, often via the sloped, paved surfaces or drainage ditches cut alongside the roads.

In the second half of the 1900s, residents and visitors alike increased in number, resulting in the construction of hotels, condos, and housing developments. In the early 1970s, sections of the reef flat at Kamalō and Pūko‘o were dredged for marina development (fig. 8). Some of the excavated material was used to alter the shape of the remains of a large fishpond, and some of it was discharged onto the reef. After completion of the dredging and reshaping of the coast, these marina projects were abandoned.

Additional development along the southern shoreline began with small-scale residential units, including low-rise condominiums and private homes. This was followed by upslope development involving large-scale clearing and grading and the building of roads, houses, walls, parking lots, and driveways. These activities altered the runoff patterns. Less water was absorbed into the ground, and surface flows became larger, more frequent, and more erosive.

Population growth on Moloka‘i also led to an increase in sewage discharge, another potential impact to the reef. The county sewage treatment plant serves only the town of Kaunakakai (J. Souza, oral commun., 2000) and uses injection wells on the plant site west of town and a quarter mile north of town, in Kaunakakai Gulch. Newer residences outside the town have septic systems, while the older ones have cesspools. Condominiums have their own small primary treatment systems with on-site injection wells. There is a potential—as yet undocumented—impact on the reef from the migration of sewage through ground-water seepage. Nutrients in the sewage may contribute to blooms of undesirable algae and cyanobacteria along the inner reef flat near residential areas.

The Twenty-First Century

Centuries of human activity have clearly had an impact on water quality and reef condition along the Moloka‘i south coast. Human activities that have adversely affected much of the south coast include coastal dredging at Pūko‘o in the east, wharf construction and sugar cane farming in the central part of the coast, and heavy cattle grazing on the west end. Although the impact from these activities has been severe, evidence indicates that once the activities ended, water quality improved and the adjacent reef began to recover. Assessment will continue for many years in an effort to discern the degree of improvement in both the water and the reef. Coastal waters off Pālā‘au, for example, are relatively clear compared to those off Kawela, and the coral cover on the reefs is increasing.

Many activities that occur in watersheds have a lingering effect, or legacy. Muddy sediment introduced into gullies, stream channels, and the coastal plain remains there for many years, but ultimately it is eroded and transported to the reefs. The greatest threats to reefs and to water quality are activities that expose upland soils to accelerated erosion and transport. Two of the principal causes of current soil loss from south Moloka‘i watersheds are the stripping of vegetation by fires and the destructive grazing of feral goats (fig. 9).

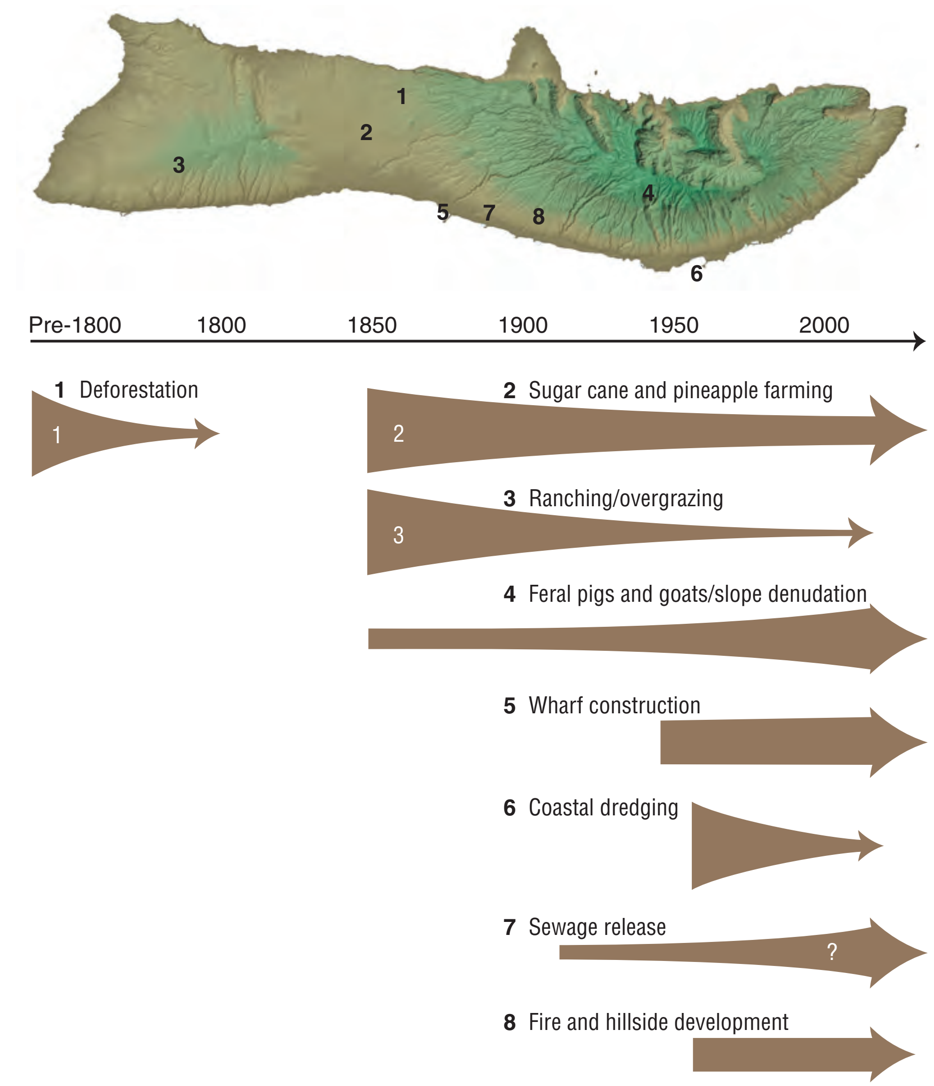

Figure 9. This map and chart summarize the human activities that have influenced watershed character and soil loss on Moloka‘i over several centuries. The locations are somewhat generalized; although the locations of some activities are well known (farming in the Ho‘olehua Saddle, for example), the locations of others, such as fires and feral grazers, are widespread and change through time. The time line illustrates the approximate timing for each activity that has caused soil loss and altered conditions on the Moloka‘i reef. Although some past activities seem to have had a severe impact, the reef appears to be recovering now that the activity has ceased or diminished. Some activities, in particular feral grazing, fire, and hillside and coastal construction still have the potential to continue degradation of the reef. Ongoing studies by U.S. Geological Survey scientists show that in some upland areas the damage to the terrain will be difficult to repair. Loss of vegetation leads to erosive overland flows and soil loss, making it difficult for vegetation to become reestablished. Note that the impact from sewage release into the subsurface is essentially unknown, and that at present, damage from feral goats is a leading contributor to soil loss and reef degradation.

Figure 10. The denuded hill slopes of eastern Moloka‘i upslope from Kamalō. Feral goats strip the grasses and young shoots before they can develop sufficient root structures to hold soil or a canopy to protect against direct rain action. Infrequent fires exacerbate the problem of vegetation loss.

Federal, State, and local organizations have recognized the threat to Hawaiian coral reefs from land-derived sedimentation. Together they have developed a Local Action Strategy (LAS) under the auspices of the U.S. Coral Reef Task Force to address land-based pollution. The LAS focuses on three areas in Hawai‘i, one of which is the Kawela to Kapualei area of east Moloka‘i. The LAS is watershed based and incorporates the native management system for lands and natural resources, the ahupua‘a. The objectives of the LAS are threefold: (1) reduce pollutant load to surface water and ground water, (2) improve understanding of the link between land-based pollution and coral-reef health, and (3) increase awareness of pollution prevention. The LAS proposes specific positive actions to address the problems of soil erosion in the Kawela-Kapualei area and the consequent damage to coastal water quality and the reef:

- fencing and other procedures to control feral grazers and reduce the impact of grazing,
- educating and training local residents about fire management,
- restoring the watersheds with native vegetation, and
- constructing sediment basins to capture land-derived silt before it reaches the ocean.

Construction of sediment basins is costly, and thus it is uncertain whether they will be built. The other measures, along with a program to reduce the total number of goats, will likely reduce sediment runoff.

Summary

Although landscape change is a continuous and anticipated part of all natural systems, the rate of erosion, deposition, and coastal change in South Moloka‘i has been altered significantly by human activities that range from farming and ranching to the introduction of feral grazers. These activities were not confined to any one part of the island, nor was any single activity responsible for the changes to the watersheds. The changes visible today result from the cumulative effects of many different activities over decades or, in some cases, centuries (fig. 10).

During the past few years, the residents of Moloka‘i have recognized the extent to which they affect the rate of change in their environment and have initiated efforts to understand and possibly reverse the effects. Today scientists continue to study the upland regions and the processes that erode and transport sediment to the reef. On the reef, they examine physical evidence of the impact of upland watershed change on the coral community. They seek to identify and quantify the rate of change and learn the causes of both past and present change. The goal is a worthy one: knowledge of Moloka‘i’s past will help the residents deal more effectively with present and future threats to their coral reefs.

Suggested citation:

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