CHAPTER 8

The Seaweed and Seagrass Communities of Moloka‘i

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The marine environment around the island of Moloka‘i has many different types of habitats and unique marine communities. The focus of this chapter is to describe the marine plant communities around the island, with a general focus on those off the south shore. Both seagrasses (true marine plants) and the seaweeds (which are not considered to be "true" plants, see below) will be discussed in detail. Seaweeds or marine algae are ocean-dwelling photosynthetic organisms that belong to several diverse evolutionary lines, the most prominent being the green algae (chlorophytes), the brown algae (phaeophytes), and the red algae (rhodophytes). There are many other groups of photosynthetic organisms in the ocean, including photosynthetic bacteria (cyanobacteria), but they are not the focus of this chapter.

The Hawaiian Islands support more than 500 species of marine algae (Abbott, 1999; Abbott and Huisman, 2004), and species new to science are still being discovered on a regular basis. To Hawaiians the word "limu" is used to describe seaweeds, many of which are important for food and/or cultural activities. The term seaweed specifically refers to photosynthetic marine organisms that are members of a disparate kingdom of organisms known as kingdom Protista. These organisms are not considered to be true plants, even though the evolutionary ancestor of land plants was a green alga. They are generally simpler in organization, lacking typical plant organs such as leaves, roots and stems, and they do not reproduce by making fruits and seeds. Because seaweeds are immersed in water, they generally do not need specialized organs to take up water and nutrients (although some seaweeds do have specialized structures). Instead, the entire algal thallus (body) can photosynthesize and absorb nutrients from the water.

There are true marine plants, known as seagrasses, which also live completely immersed in seawater and are often quite abundant in shallow back-reef environments on coral reefs. Seagrasses can form dense meadows, which can be important nursery habitats for a number of commercially important fish and invertebrate species (Mumby and others, 2004; Dorenbosch and others, 2005; Gratwicke and Speight, 2005; Valentine and Heck 2005). The following sections will focus on the benthic (bottom dwelling) communities around Moloka‘i, with an emphasis on seaweeds, seagrasses, and some cyanobacteria.

A number of physical and biological factors influence the distribution and abundance of seaweeds and seagrasses on tropical reefs (Lobban and Harrison, 1994). Physical factors include substrate type, temperature, salinity, light levels, hydrodynamics or wave exposure, nutrient availability (nitrogen and phosphorous), sedimentation, and others. Some of the most important biological factors affecting the distribution and abundance of seaweed communities on coral reefs are predation or grazing by herbivores (both fish and invertebrates that eat seaweed) and competition with other benthic organisms (other seaweeds, seagrasses, and corals) (Carpenter, 1986; Hughes and others, 1999b; McCook, 1999; Miller and others, 1999; Smith and others, 2001; Stimson and others, 2001; Thacker and others, 2001; Jompa and McCook, 2002; Diaz-Pulido and McCook, 2003; Jompa and McCook, 2003; McClanahan and others, 2003).

One of the most intriguing areas of research in coral reef ecology has been to understand how and why corals dominate the landscape in tropical marine environments while plants dominate most other ecosystems on the planet (Odum and Odum, 1955). Reef ecologists generally believe that a combination of physical and biological factors favor the dominance of corals over algae in healthy or pristine reef-slope areas. Humans, however, can have dramatic effects on coral reef communities by altering any of the above factors, often shifting the competitive edge away from the corals and in favor of faster growing algae (Hughes and others, 1999b; Hughes and Connell, 1999; Jackson and others, 2001; Aronson and others, 2003; Hughes and others, 2003; Pandolfi and others, 2003a, b; Bellwood and others, 2004; Pandolfi and others, 2005). There are, of course, always exceptions, and it is worth mentioning that in the remote Northwestern Hawaiian Islands seaweeds are often more abundant than corals (Vroom and others, 2005) in the absence of any chronic human disturbance (this is generally believed to be the result of low water temperature).

From a biological perspective, dense populations of grazers (for example, surgeonfish, parrotfish, and sea urchins) on healthy reefs help keep algae cropped to low levels (Carpenter, 1986; McCook, 1999; Miller and others, 1999; Smith and others, 2001; Thacker and others, 2001; Belliveau and Paul, 2002; McClanahan and others, 2003). Generally, on healthy or pristine reefs where fish and invertebrate are abundant, the algae that are present are either very small turfs that have fast growth rates or are either chemically and/or physically defended against grazers (Carpenter, 1986). Experimental evidence suggests that the loss of gazers from reefs through overfishing or from disease outbreaks can allow algae to begin overgrowing corals and eventually cause a phase shift in which long-lived, slow-growing corals are replaced by fleshy, fast-growing seaweeds (Hughes and others, 1987; Hughes, 1994; Hughes and others, 1999b; McCook, 1999; Jackson and others, 2001; Bellwood and others, 2004).

From a physical perspective, the availability of nutrients, primarily nitrogen and phosphorus, can also influence the growth rates and abundance of algae on reefs (Smith and others, 1981; Bell, 1991; Bell, 1992; Lapointe, 1997; Smith and others, 2001). Most reefs have developed in the clear, warm, and nutrient-deficient waters of the tropics. The coral

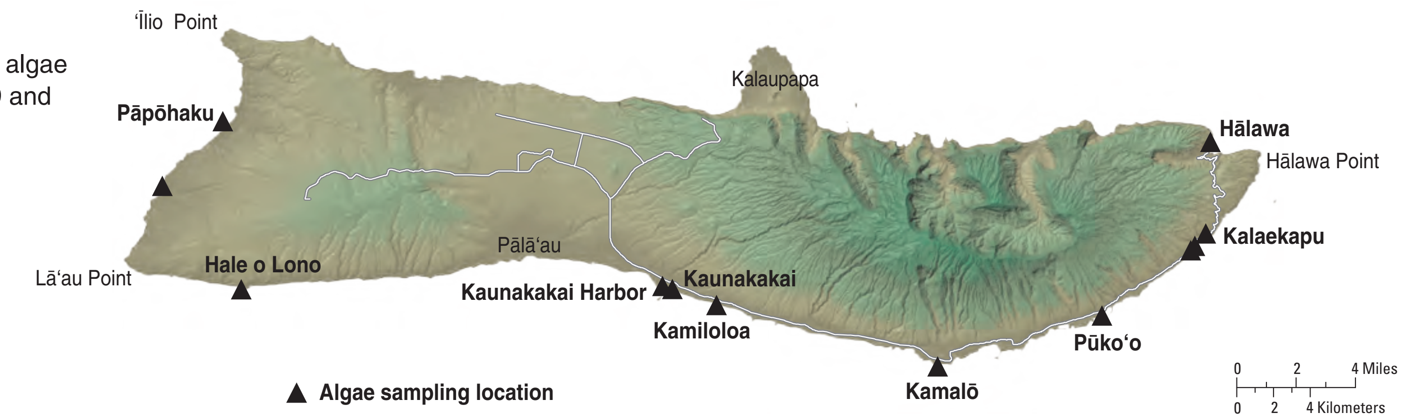

Figure 1. Map of Moloka‘i showing the algae sampling sites surveyed between 1999 and 2003. See text for further details.

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organisms and their symbiotic zooxanthellae (microscopic single-celled algae that live inside the coral tissue) are extremely efficient at using nutrients and are able to survive with very little external nutrient input. Reef algae and seagrasses, on the other hand, need external sources of nitrogen and phosphorus to survive. These organisms are able to absorb nutrients from the water column, sand, or sediment. On healthy reefs the low input of nutrients generally limits the growth of algae. In some cases where nutrient inputs are high (for example, from sewage outfalls, terrestrial runoff containing agricultural fertilizers, landscaping, river runoff, sedimentation), algae may be able to overgrow corals and become dominant, even occasionally forming large blooms, as can be seen on some of the shallow reefs of Maui (Smith and others, 2005).

The introduction of exotic or nonnative species has caused numerous problems in the Hawaiian Islands, both on land and in the sea. These invasive species are seen as one of the largest threats to global biodiversity, because they are often able to outcompete native species (Vitousek and others, 1997) and even cause extinction events. In Hawai‘i, this is particularly a problem because there are so many endemic species (species which are only found in Hawai‘i) that are highly specialized to specific habitats. Several species of marine algae have been introduced to Hawaiian reefs, primarily for experimental aquaculture (Smith and others, 2002). Unfortunately, many of these species have spread from their initial points of introduction (mainly on O‘ahu) and have become quite abundant on the shallow reef-flat environments around the Hawaiian Islands, including Moloka‘i (Smith and others, 2002; Smith and others, 2004; Conklin and Smith, 2005; Smith and others, 2005). Some of these exotic species are a particular concern because they have been shown to cause reductions in species diversity and coral cover on O‘ahu (Smith and others, 2004).

Different Algal Communities and Functional Groups

Marine algae can be classified in several different ways. The most general classification for reef algae includes three functional groups: macroalgae, turf algae, and crustose coralline algae (Littler, 1980; Littler and others, 1991). Macroalgae are generally taller than a few centimeters and include hundreds of species in the Hawaiian Islands. These species can be either fleshy or calcified (containing calcium carbonate). Calcified species usually have a whitish hue and may have a chalky texture. Turf algae represent a community of very small (less than a few centimeters tall), usually filamentous algae including hundreds of species and even juvenile stages of larger algae. Algal turfs are an important food source for many reef fish species. Finally, crustose coralline algae (CCA), or heavily calcified pink crusts, look like a nonliving pink pavement. The CCA are incredibly important for reef building, as they are known to cement corals and other reef components together. They are also extremely strong and can withstand very large wave stresses. CCA commonly form an “algal ridge” along the reef crest, which is the portion of the reef where waves break (Macintyre and others, 2001). It is the CCA and the algal ridge, along with the corals themselves, that build reef structure. CCA also play an important role in the development of reefs because they are the primary substratum upon which many coral larvae settle (Harrington and others, 2004). Essentially, the CCA not only help to build reefs but they facilitate the persistence of corals as well.

Algal Communities of Moloka‘i

The remaining sections of this chapter will discuss the benthic marine algal communities around Moloka‘i, ranging from Hālawa Bay in the east, around the south shore, and ending at Pāpōhaku Beach Park in the west (fig. 1). The north shore of the island is generally very difficult to access and has not been surveyed or assessed by the authors, so it will not be discussed here. Brief descriptions of the marine communities from each of the other coastal regions (west, south, and eastern coasts) will be accompanied by photographs of some of the dominant algal species or groups found in these respective areas. The majority of the data presented here come from two years of shallow-water surveys that were conducted by snorkel, and only a limited amount of data is available to describe the offshore reef-slope communities from Kamalō, Kamiloloa, and Pālā‘au (fig. 1). Lastly, the deep-water algal communities off the south shore will be discussed briefly, using the results of some recent (2004) submersible and ROV (remotely operated vehicle) surveys.

The Eastern Shore

The eastern shore of Moloka‘i is characterized by basalt points, bays with sandy beaches, and narrow, shallow reef flats. The shoreline is part of the windward shore and is regularly exposed to waves and wind. At Hālawa Bay, large boulders make up much of the intertidal zone, and these boulders are colonized by the brown algae *Endarachne binghamiae* (fig. 2) and *Hincksia mitchelliae* (fig. 3). The boulders also provide substrate for CCA and many invertebrates such as the shingle urchin, *Colobocentrotus atratus* or hā‘uke‘uke (fig. 4) and several species of limpets (‘opihi) are common. The basalt benches and tidepools common along most of the eastern shore are generally dominated by several species of large brown algae, including *Turbinaria ornata* (fig. 5) and *Sargassum* (limu kala) (fig. 6), as well as CCA. In the shallow subtidal environments many spe-

Figure 2. The brown alga *Endarchne binghamiae* is commonly found growing on intertidal boulders in the Hawaiian Islands. The length of this species ranges from 5 to 20 cm (2 to 7.8 in).

Figure 3. The filamentous brown algae *Hinksia mitchelleae*, which is usually found growing in small clumps either on boulders or shallow basalt benches in the intertidal zone. *Hinksia* is unsually no bigger than 3 cm (1.2 in) in diameter.

Figure 4. A typical Hawaiian intertidal boulder field showing the purple shingle urchin grazing on algae. The pink crusts are crustose coralline algae (CCA) and the small brown turfs are the filamentous brown alga *Hinksia*.

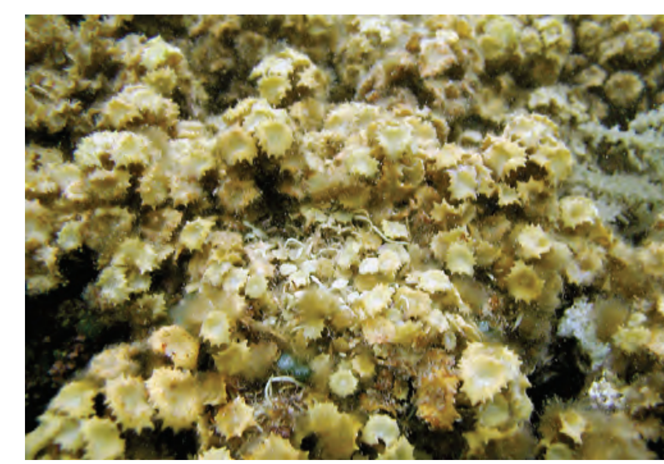

Figure 5. The brown alga *Turbinaria ornata* is commonly found growing in tidepools and in other environments of high wave energy. Individuals of *Turbinaria* can range from 1 to 30 cm (0.4 to 12 in) in length.

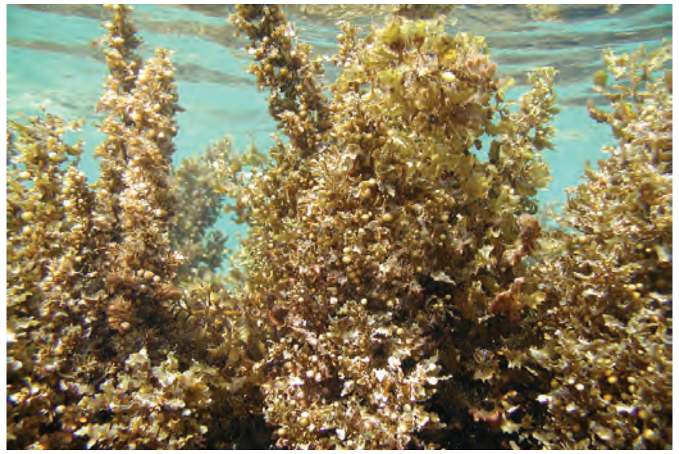

Figure 6. One of the three species of *Sargassum* (limu kala) commonly found in Hawaiian intertidal environments, especially in tidepools or on shallow reef flats. *Sargassum* species are some of the largest seaweeds in Hawaii (on average 20 cm/8 in tall) and can reach heights of nearly 1 m (3 ft).

Figure 7. The red alga *Asparagopsis taxiformis* (limu kohu) is common in shallow reef-flat environments, exposed benches, and subtidal reef environments. This alga is also known as limu kohu and is regularly eaten after being fermented to prevent poisoning from the high concentrations of ammonia contained in the alga. *Asparagopsis* is a delicate alga that is usually less than 10 cm (4 in) tall.

Figure 8. The red alga *Melanamansia glomerata* is a very common component of shallow and deeper reef communities in Hawai‘i. Many other species of algae commonly grow on top of *Melanamansia*, making it sometimes difficult to identify in the field. Individuals of *Melanamansia* are usually around 10 cm (4 in) tall.

Figure 9. *Portieria hornemannii* is a very common species of red alga found on shallow reef flats and deeper reef-slope environments in Hawai‘i. *Portieria* is a delicate alga usually less than 10 cm (4 in) tall.

Figure 10. The calcified red alga *Dichotomaria marginata* is quite common in Hawai‘i, where it is usually found growing on steep to vertical surfaces such as basalt walls or slopes. Individuals are usually less than 15 cm (5.9 in) tall.

Figure 11. *Galaxaura* species are commonly found on the exposed windward coast of Moloka‘i.

Figure 12. *Tricleocarpa* is a branching calcified red alga that is common in the shallow subtidal environments around Hawai‘i. This alga commonly grows on hard substrates in subtidal areas on both the east and west shores of Moloka‘i. *Trichleocarpa* is usually more heavily calcified than *Galaxaura* and is usually no taller than 15 cm (5.9 in).

Figure 13. The calcified green alga *Halimeda discoidea* is common in the shallow reef-flat environments on the windward shore of Moloka‘i. This species can also be found on the outer portions of the extensive shallow reef flats off the south shore. *H. dicoidea* grows in small rosettes reaching heights of 5–10 cm (2–4 in).

Figure 14. The green alga *Dictyosphaeria cavernosa*, otherwise known as "bubble algae," is common on Hawaiian reefs in both the shallow subtidal and deeper reef-slope environments. It is often seen growing between corals as shown in this picture, where it is growing under a colony of the coral *Montipora capitata*. *Dictyosphaeria* has very large cells, which are often visible to the naked eye.

Figure 15. The green alga *Codium edule* commonly grows on the bottom in shallow subtidal environments. There are numerous other species of *Codium* (limu waiwai'ole) in Hawai‘i, some of which are commonly consumed in salads.

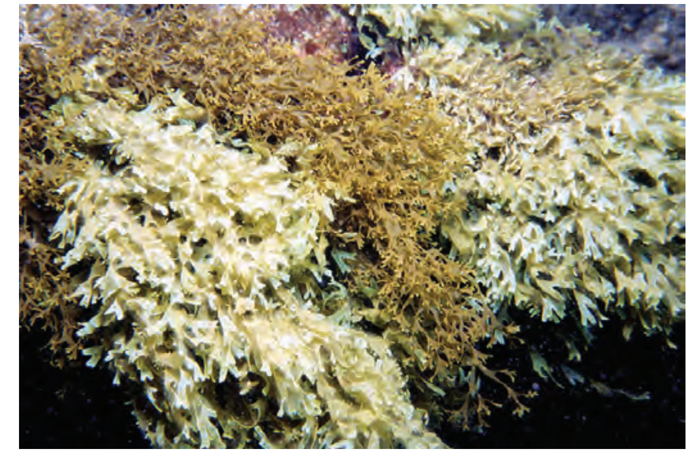

Figure 16. Several species of *Dictyota* are common in Hawai‘i, including the two pictured here. *Dictyota sandwichensis* is often an iridescent blue-green to yellow color, whereas *Dictyota acutiloba* is more of a caramel-brown color. The various species of *Dictyota* can vary in size from less than a centimeter to several centimeters in length.

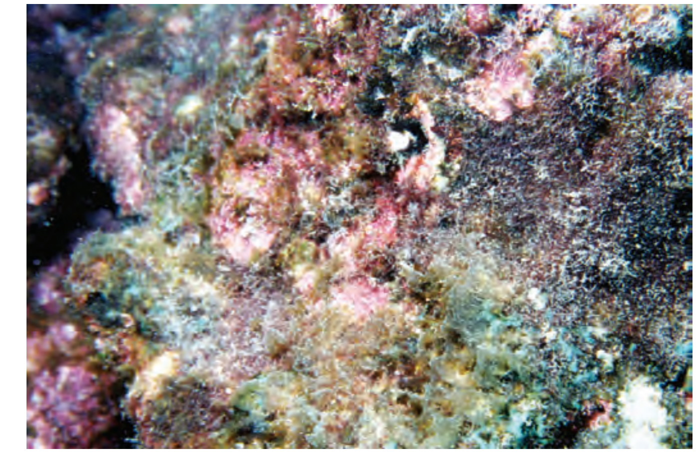

Figure 17. The mixed species communities of small filamentous algae (less than 2 cm/0.8 in tall), otherwise known as turf algae, are a very common and important component of reef ecosystems. These communities serve as the primary food source for numerous species of grazing fish and sea urchins. The turfs have extremely fast growth rates and so are considered to be an extremely efficient energy source for the reef community.

cies of red algae are common, including *Asparagopsis taxiformis* (limu kohu) (fig. 7), *Melanamansia glomerata* (fig. 8), and *Portieria hornemannii* (fig. 9), as well as some calcified red algae, including *Dichotomaria* spp. (fig. 10), *Goalaxaura* spp. (fig. 11), and *Tricleocarpa* (fig. 12). Numerous other species of algae are present, either out in the open such as *Halimeda discoidea* (fig. 13) or in the cracks and crevices, hidden away from the mouths of herbivorous fish and sea urchins. Algae present include, among many others, species of *Dictyosphaeria* (fig. 14), *Codium* (fig. 15), *Dictyota* (fig. 16), and of course turf algae (fig. 17) and CCA (fig. 18).

The South Shore

The Reef Flat

The south shore is characterized by very wide (100s of meters) shallow (0–2 m, 0–6 ft) reef flats (Storlazzi and others, this vol., chap. 3), which provide an extensive amount of habitat for marine algae. Most of these shallow reef flats are composed of a soft sandy or muddy bottom (Cochran, this vol., chap. 9) and will only support growth of algae or seagrasses that can anchor themselves into the soft substrata. Most notably, the endemic seagrass *Halophila hawaiiana* is quite abundant (fig. 19). Interestingly, *H. hawaiiana* exhibits two different growth forms on Moloka‘i. The common morphology is shown in figure 20, where the leaves of the seagrass are oval; the other growth form is shown in figure 21, where the leaves are more linear in shape. It is unclear if these two growth forms are different genetic entities (different species) or if they are just responding to differences in environmental conditions. Nonetheless, it is interesting that they are both found growing side by side on Moloka‘i. *Halophila decipiens* looks very similar to the oval morphotype of *H. hawaiiana* and may also be present on Moloka‘i. These seagrasses are particularly important on shallow reef-flat and/or lagoonal areas for a number of reasons. Primarily, they help to stabilize sediments by anchoring their roots into the soft bottom, inhibiting erosion and preventing sediment transport onto the fore reef, where it could smother the coral community and associated fauna. Seagrasses are also an important food source for many organisms, including sea turtles. Furthermore, seagrasses are known to provide habitat and shelter for numerous species of fishes and invertebrates during different stages of their life cycles.

In addition to the seagrasses, several species of macroalgae are found on these shallow reef flats growing on small pieces of reef rubble or other occasional areas of hard bottom, including some weedy nonindigenous invasive species. The invasive red alga *Acanthophora spicifera* (fig. 22) is quite common along the entire south coast and can be found growing from shore all the way out to the reef crest. This alga can be seen overgrowing or smothering many species of coral (fig. 22). Another invasive red alga, *Hypnea musciformis* (fig. 23), can also be found on the south shore but is most common near the town of Kaunakakai. *Hypnea* grows abundantly on the shallow reef flats and sometimes washes ashore (fig. 24). This alga forms massive blooms on the island of Maui, likely as the result of increased nutrient input from shore (Smith and others, 2002).

Several species of *Gracilaria* can be found on Moloka‘i's south shore. *Gracilaria coronopifolia* (limu manauea) (fig. 25) grows in large clumps on the shallow reef flats on Moloka‘i's south shore. This species is regularly harvested for food and can be found in the common raw fish salad known as "poke." *Gracilaria parvispora* (long ogo) (fig. 26) can occasionally be found growing attached to small rocks close to shore on the reef flats, but this species is also harvested regularly and is uncommon in the wild. Both ogo and manauea are grown on Moloka‘i in fishponds or other areas for human consumption. The invasive species *Gracilaria salicornia* (gorilla ogo) (fig. 27) is also present on the shallow reef flats of the south shore. This species was introduced to Moloka‘i in the 1980s from O‘ahu (the O‘ahu population originated from a population found in Hilo, which was most likely accidentally introduced by ships from the Philippines before the 1900s, during the whaling era). *G. salicornia* was only found at a few locations on Moloka‘i—specifically Pūko‘o fishpond and in front of the canoe club at Kaunakakai Harbor—but it may be spreading. This species is invasive on O‘ahu, where it is one of the most dominant species in Waikīkī and in Kāne‘ohe Bay (Smith and others, 2004).

Several other species of red algae can be found on the shallow reef flats of Moloka‘i, but *Spyridia filamentosa* (fig. 28) is probably among the most common. This species is easily recognized because the numerous small hairs that cover the thallus usually trap sediment, giving it a dirty appearance. Other common species include members of the brown

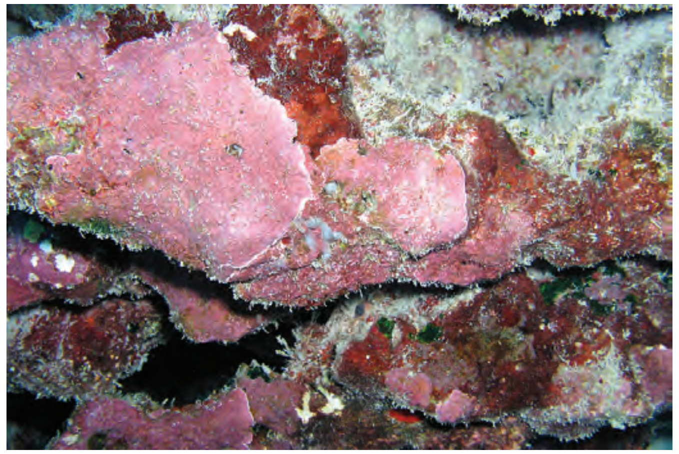

Figure 18. Crustose coralline algae (CCA) are pictured here in various shades of pink. CCA are heavily calcified red algae that help to cement and bind reefs together. These organisms are quite common in all reef zones in Hawai‘i and include around 25 species, although very little is known about their taxonomy. CCA look more similar to pink cement or rock than they do to other algae.

Figure 19. A meadow of the endemic seagrass *Halophila hawaiiana* growing along the south shore of Moloka‘i. Leaves of *Halophila* are usually less than 5 cm (2 in) in height, but meadows can cover several hundred square meters.

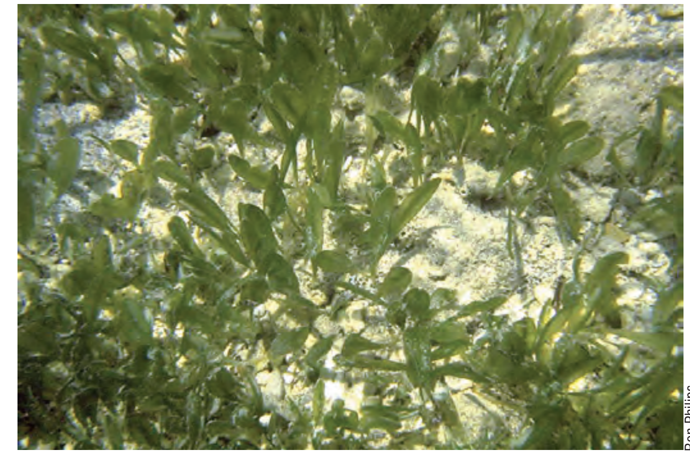

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Figure 20. The common growth form of the endemic Hawaiian seagrass *Halophila hawaiiana* (note the oval or paddle-shaped leaves) growing on the shallow reef flats of south Moloka‘i.

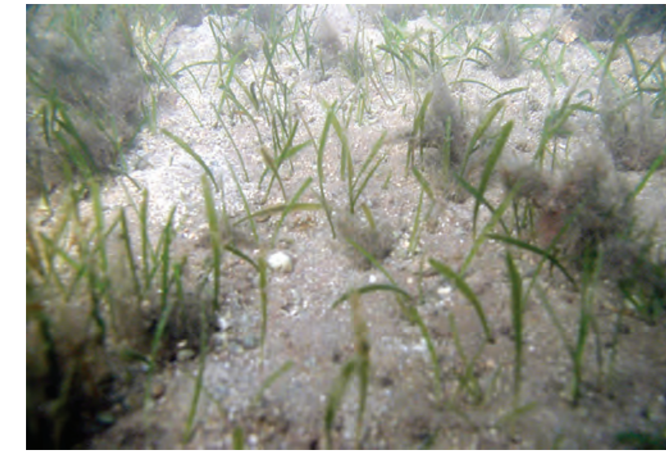

Figure 21. The more elongated and linear-shaped leaves of a different growth form of *Halophila hawaiiana* can also be found growing on the shallow reef flats of Moloka‘i.

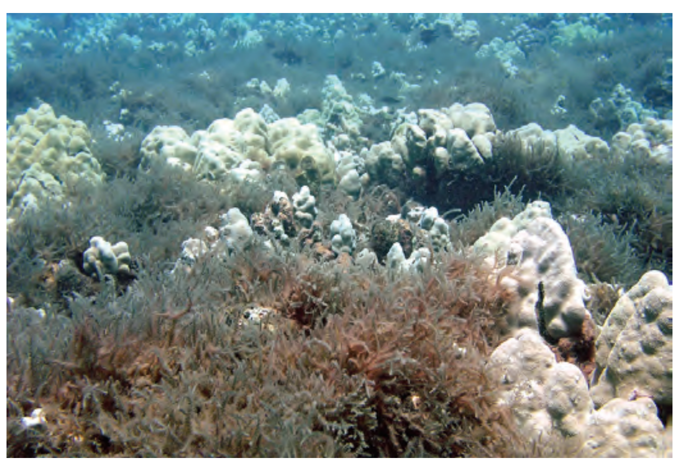

Figure 22. The invasive red alga *Acanthophora spicifera* can be seen in the foreground of this picture, where it is growing over the coral *Porites lobata*. This alga is one of the most common species of algae on the south shore of Moloka‘i and can be found from Hale O Lono Harbor in the west all the way to Kalaekapu in the east. *A. spicifera* was first introduced to O‘ahu in the 1950s by a heavily fouled barge that originated from Guam. *A. spicifera* is usually less than 15 cm (5.9 in) tall, with small spike-like side branches.

Figure 23. The invasive red alga *Hypnea musciformis* was first introduced to O‘ahu in the 1970s for experimental aquaculture and has now spread to all of the main Hawaiian Islands except the Big Island of Hawai‘i. It is quite common on the south shore of Moloka‘i, and it forms large blooms on the island of Maui.

Figure 24. The red alga *Hypnea musciformis* washed up on beaches. *A*, A small band of *H. musciformis* lines the beach of Kamiloloa at low tide. *B*, Thousands of pounds of this alga wash onto the beaches every day on Maui (photo taken at north Kīhei).

Figure 25. *Gracilaria coronopifolia*, or limu manauea, growing on the shallow reef flat along the south shore of Moloka‘i. This alga has thin branches (1 mm), but an individual can grow to the size of a bowling ball.

Figure 26. *Gracilaria parvispora*, or long ogo, grows on the shallow reef flat along the south shore of Moloka‘i. This species is also commercially cultivated on Moloka‘i in fishponds and other areas for food (limu poke) and is also used as garnish for meals in restaurants. This species is usually very long and wispy, with branches growing to 50 cm (19.6 in) in length.

Figure 27. The invasive red alga *Gracilaria salicornia,* or gorilla ogo, growing near Kaunankakai Harbor. This alga was introduced to Moloka‘i from O‘ahu in the 1980s for aquaculture projects that were later abandoned. This species is highly invasive on O‘ahu and has the potential to become a problem on Moloka‘i. *G. salicornia* is usually yellow, orange, or brown in color and can grow in large clumps 30 cm (12 in) or more in size.

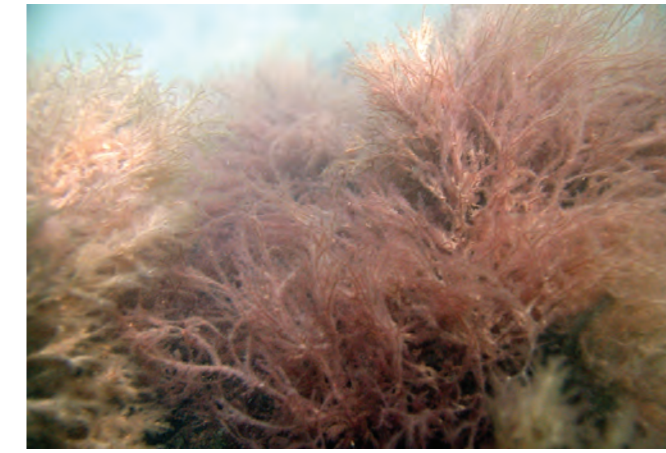

Figure 28. The red alga *Spyridia filamentosa* is quite common on the shallow reef flat of Moloka‘i. This species is often covered with a dusting of sediment and seems to be able to tolerate growing in extremely muddy areas. *Spyridia* has soft delicate branches and can grow up to 20 cm (7.8 in) in height.

Figure 29. The lightly calcified brown alga *Padina* growing on the reef flats near Kamiloloa. This species is common in muddy areas and can grow quite large, with blade diameters up to 25 cm (10 in).

Figure 30. The green alga *Caulerpa sertulariodes* growing in the sand on the shallow reef flat of the south shore of Moloka‘i. Most species of *Caulerpa* have small root-like rhizoides, a horizontal runner, and upright blades. In this species the blades resemble a fern frond but are only 2–3 cm (0.8–1.2 in) tall.

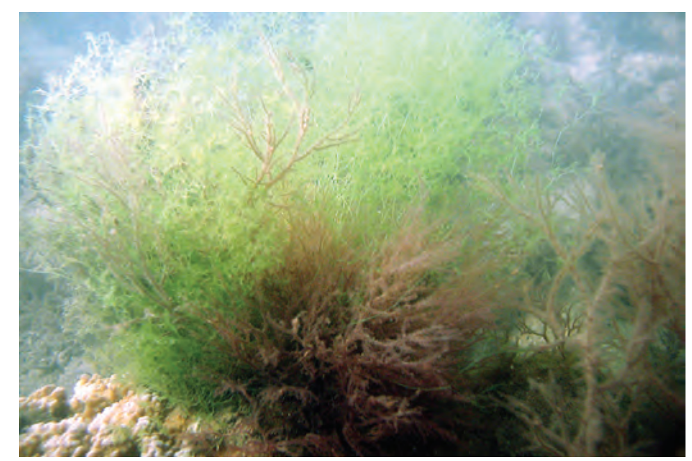

Figure 31. The filamentous green alga *Cladophora vagabunda* growing intermixed with the red alga *Spyridia filamentosa* (lower right). Most species of *Cladophora* are very fine and delicate, but they can grow quite large (~20 cm/7.8 in tall), often resembling green cotton candy.

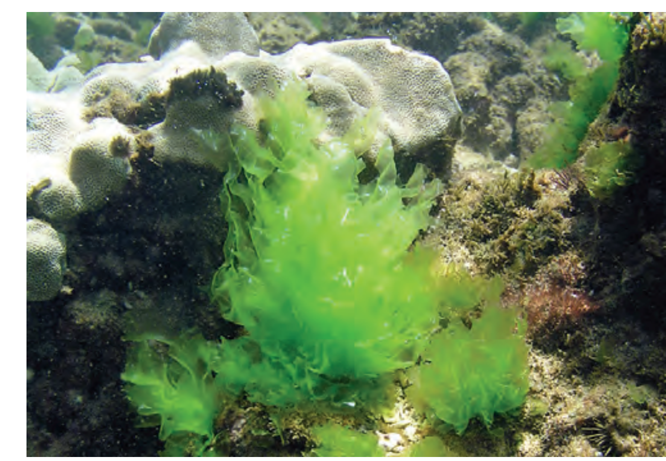

Figure 32. The green alga *Ulva fasciata*, or limu pālahalaha, is common in shallow nearshore environments, especially near nutrient or fresh sources such as springs or streams. *Ulva* is also known as sea-lettuce because its bright green blades resemble leaves of lettuce grown on land.

algal genus *Padina* (fig. 29), which are easily recognized by the rings of calcification that lightly cover the flat leaf-like thallus. Several species of *Caulerpa* can be found in Hawai'i, and *Caulerpa sertularioides* (fig. 30) is quite common on Moloka'i. The calcified green alga, *Halimeda discoidea* (fig. 13) is locally abundant, growing in small clumps. Other green algae such as the filamentous *Cladophora vagabunda* (fig. 31), the blade *Ulva fasciata* (limu pālahalaha) (fig. 32), and the commonly eaten *Enteromorpha* spp. (limu 'ele'ele) (fig. 33) are also common, especially in areas close to shore near fresh water sources such as springs or stream mouths. The cyanobacteria *Lyngbya majuscula* (otherwise known as swimmer's itch because it produces a toxin which can irritate the skin; fig. 34) grows on top of other algae on the reef flats. *Lyngbya* seems to bloom seasonally in the summer, when it can become quite abundant; by the fall it nearly completely disappears.

In summary, the shallow reef flat and back reef habitats on Moloka'i are dominated by macroalgae, seagrass, soft sediment, and reef rubble. These areas seem to be quite productive, and because of numerous factors including extensive habitat, they support a diversity of algal species. The high amount of terrigenous sediment deposited in these areas may also contain both organic and inorganic nutrients, thus potentially fertilizing the algal communities. The three invasive nonindigenous algae found on the south shore reef flats seem to be able to outcompete native species in other areas around the Hawaiian Islands and therefore are of concern for marine resource management. The reef flats are important resources, because they support numerous fish, invertebrate, and seaweed species, of which many are harvested for subsistence consumption.

The Reef Slope

There is a limited amount of information known about the algal communities in the deeper (2–20 m, 6–60 ft) reef-slope environments around Moloka'i. However, in a single survey in 2002, two divers collected more species of algae (as many as 85) from Pālā'au, Kamiloloa, and Kamalō than from any other sites surveyed around the eight main Hawaiian islands that same year. These sites represent some of the highest diversity sites for algae that the authors have seen. Although most of the species were members of the turf community and were small filamentous forms, several species of red macroalgae were also quite common. Species such as the fleshy red-bladed *Kallymenia sessilis* (fig. 35) and *Halymenia* sp. (fig. 36) were present. The brilliantly iridescent red algal species, including members of the genera *Halicrysis* (fig. 37), *Dasya* (fig. 38), *Martensia* (fig. 39), and *Neomartensia* (fig. 40) and *Acanthophora pacifica* (fig. 41) were all present.

In the deeper areas off the reef slope, the green alga *Halimeda kanaloana* becomes the dominant benthic organism in soft sandy areas. This endemic species forms extensive meadows (fig. 42) in the soft bottom areas off the south shores of Moloka'i, Lāna'i, Kaho'olawe, and Maui. It generally occurs in depths ranging from less than 1 m to more than 90 m (300 ft) (Verbruggen and others, 2006). All species of *Halimeda* are heavily calcified and are important sand producers. When these organisms reproduce, they relocate all of their intracellular material into their gametes, which are then released by the thousands into the water column—only an empty white skeleton of the adult plant is left. Usually within a day, the adult plant crumbles into a pile of small calcium carbonate discs that eventually break down into sand (fig. 43; Field and others, this vol., chap. 17). This process is easy to recognize in areas where *Halimeda* is abundant, because the plantlike segments are still identifiable. Although there are several other sand producers in the tropics, *Halimeda* is likely to be among the most important because of the fast turnover rates of these plants.

The reef slope communities along the southeast and southwest shores of Moloka'i are largely dominated by hard corals, but the algal communities are also incredibly diverse and are composed of some rare species. The reef slope communities near Kaunakakai have very low coral cover (Jokiel and others, this vol., chap. 5), and are predominantly covered in fleshy algae such as *Spyridia* and thick stands of turf algae. Along most of the south shore, the green alga *Halimeda* forms extensive meadows (fig. 42) in the waters beyond the reef slope, extending out into deep water.

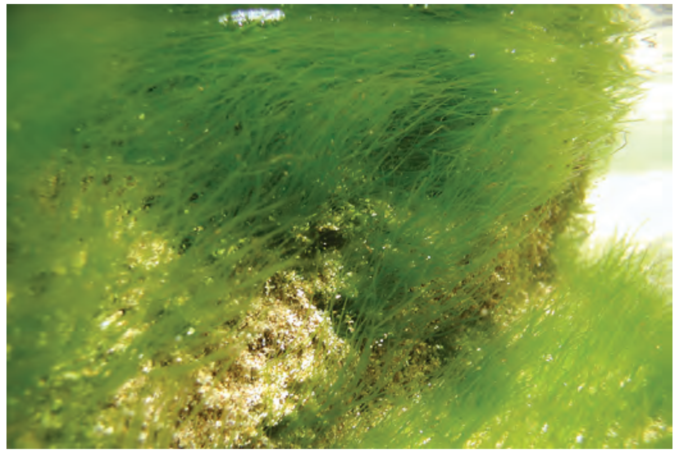

Figure 33. *Enteromorpha* (this alga is now considered to be in the genus *Ulva*, but it often grows in tubes rather than sheets), or limu 'ele'ele, can be seen growing at the land-sea interface and is often common in brackish water where springs or streams enter the marine environment. Individual tubes of *Enteromorpha* can reach more than 30 cm (12 in) in length.

Figure 34. The cyanobacterium *Lyngbya majuscula* is often found growing on top of other algae such as *Sargassum*. This species often forms large ephemeral blooms in the summer. It also produces a toxin that has been known to cause skin rashes in swimmers.

Figure 35. The fleshy red-bladed *Kallymenia sessilis* growing in the interstices of the coral *Monitpora capitata*. *Kallymenia* is usually 5–10 cm (2–4 in) in height.

Figure 36. The large, dissected, red-bladed *Halymenia* is common in wave-swept subtidal habitats in Hawai'i. Blades of *Halymenia* can reach up to 40 cm (15.7 in) in height, but most individuals are 20 cm (7.8 in) or less.

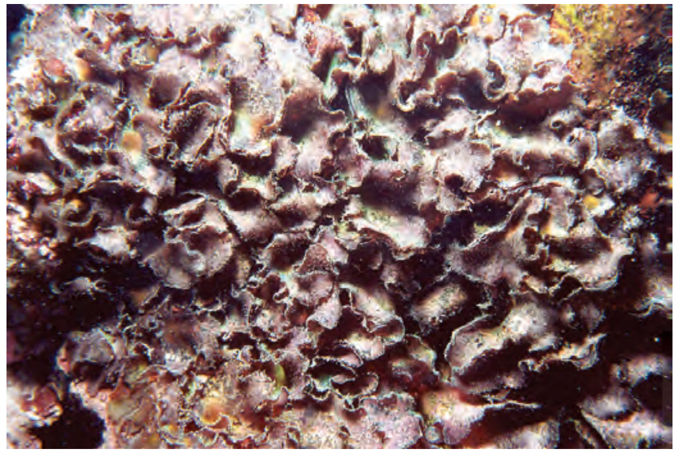

Figure 37. The golden, iridescent red alga *Halycrisis* is common at Pālā'au. This alga grows tightly adhered to hard substrates and is no taller than 5 cm (2 in).

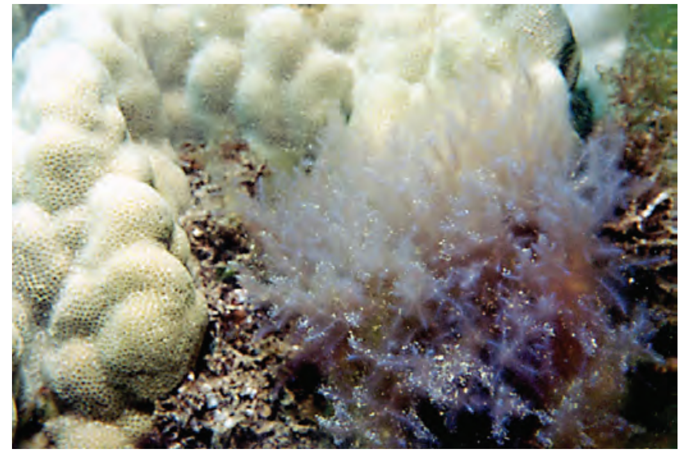

Figure 38. The delicate iridescent red alga *Dasya irridescens* is shown here growing next to the coral *Porites lobata* (lobe coral). *Dasya* grows up to about 10 cm (4 in) in height.

Figure 39. The fragile and iridescent red alga *Martensia fragilis*. This alga can vary in color from blue to purple to red and orange and is usually 5-10 cm (2-4 in) in height.

Figure 40. The delicate mesh-like iridescent red alga *Neomartensia flabelliformis* resembles gauze. This species is very fragile and is usually 5-15 cm (2-5.9 in) in height.

Figure 41. The blue to purple iridescent red alga *Acanthophora pacifica*. This species is far less common than the invasive counterpart, *Acanthophora spicifera*. *A. pacifica* is usually about 5 cm (2 in) in height.

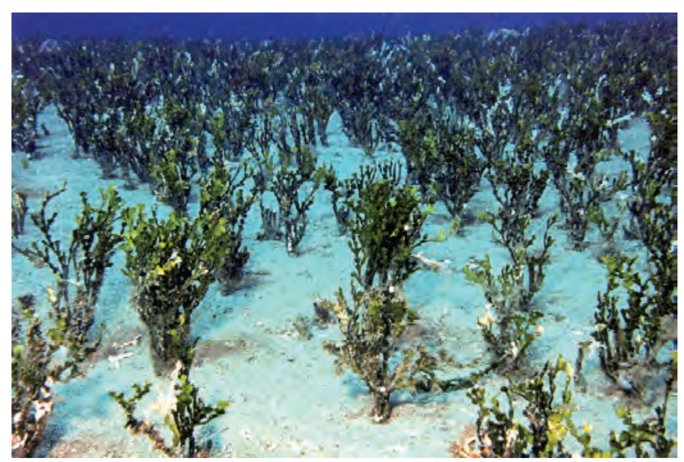

Figure 42. A meadow of the calcified green alga *Halimeda kanaloana* off Kamiloloa in 11 m (35 ft) of water. This species forms extensive meadows on the deep reef slopes off Moloka'i and Maui. Most species of *Halimeda* are important producers of sand in the tropics. This species is among the largest *Halimeda* in Hawaii and can be more than 30 cm (12 in) tall.

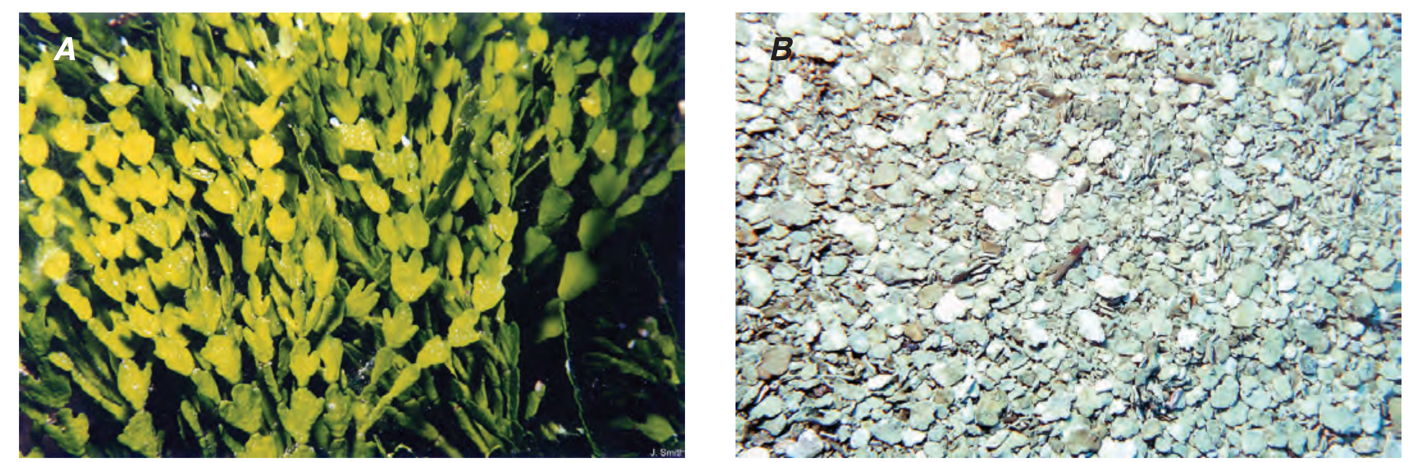

Figure 43. *Halimeda kanaloana*. *A*, A close-up of live *H. kanaloana*. *B*, Sand that is composed largely of recently dead *Halimeda* (note the oval-shaped disks).

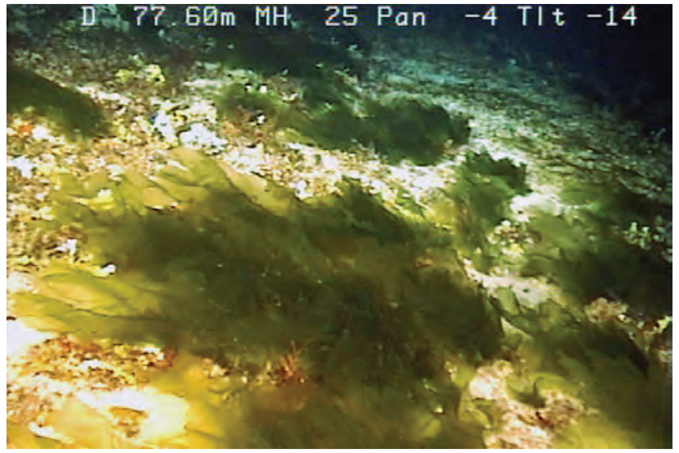

Figure 44. Large (~20 cm/7.8 in) green blades of the genus *Ulva* at 77-m (254 ft) depth. This chlorophyte covers large expanses of this deep water rubble zone.

Figure 45. Two different *Codium* species at 67-m (221 ft) depth; one is long (~15 cm/5.9 in) and lightly branched, while the other is short and more densely branched.

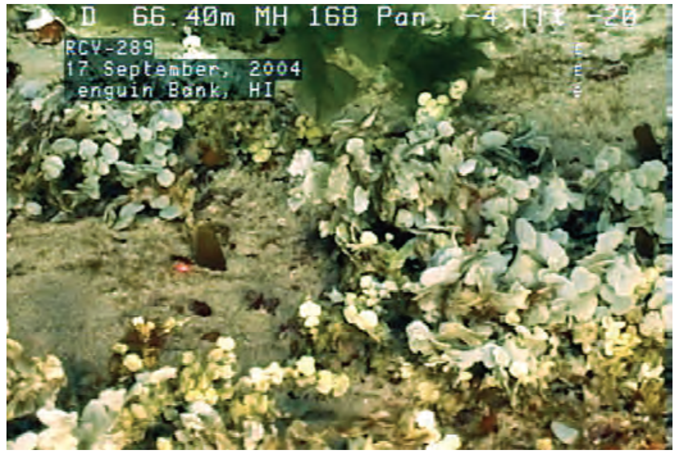

Figure 46. *Halimeda* spp. found growing on hard substrate at 67-m (221 ft) depth. These species often form clumps or large mounds in these deep-water habitats.

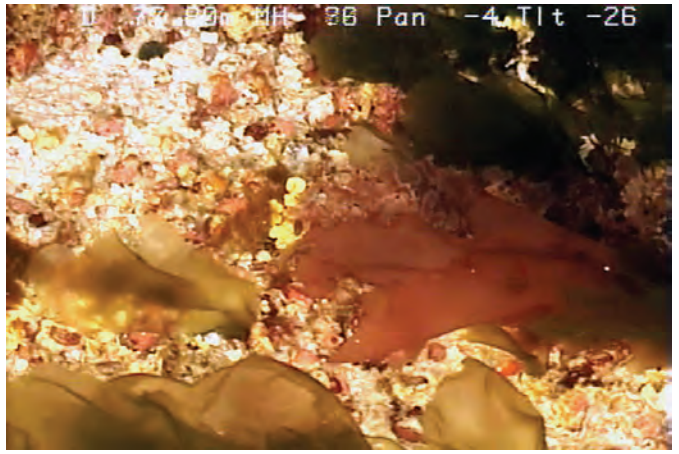

Figure 47. Unidentified red algal blades growing intermixed with the green alga *Ulva* in the rubble zone at 70-m (230 ft) depth.

Deep-Water Communities

In the deeper waters off south Moloka‘i, the bottom is a mix of soft sand, hard carbonate, rubble, and large areas covered by small balls of calcified red algae called rhodololiths. Areas that were surveyed include depths from about 60 to 120 m (~200 to 400 ft) on three different occasions in 2004 with a submersible and a remotely operated vehicle. Despite the low light levels at these depths, there was a high abundance and diversity of macroalgae. The most common large macroalgal group encountered was the chlorophyte *Ulva* (fig. 44), with *Ulva* sp. blades up to 2 m (6 ft) in length. This genus usually occurs in the intertidal zone, yet we found that it was common (as much as 25 percent cover) from 60 to 100 m (~200 to 330 ft) depths. Other common green algal genera were *Codium* (fig. 45) and *Halimeda* (fig. 46). At least three different species of *Codium* and three different species of *Halimeda* were observed, although species identifications are still pending. Many fleshy red algal blades (figs. 47, 48) were observed, but these were not collected because of strong currents. These fleshy red algae were abundant on hard substrates over the entire depth range surveyed. Large scattered clumps of the brown alga *Spatoglossum macrodentum* were also observed on hard substrate. Small filaments and clumps of the filamentous green alga *Cladophora sericea* were observed floating in the current and being transported across the bottom. A dense *Halimeda kanaloana* meadow (fig. 49) was discovered starting at 86 m (284 ft) depths in soft sediments, and it appeared to continue into shallower water.

Overall, the deep-water macroalgal community is very rich and abundant, likely forming unique habitats and acting as a food source for numerous organisms. We did not observe any invasive or introduced macroalgae in the deep-water environment, although the invasive green alga *Avrainvillea amadelpha* has been observed in similar habitats in deep water off of O‘ahu. Exploration of these unstudied environments is likely to yield the discovery of many species of algae, invertebrates, and even fishes that are new to science.

The West Shore

Very little is known about the benthic communities off the west shore of Moloka‘i. The southwest section of coast consists of a few small bays with black sand beaches and basalt points, whereas the northwest coast is largely made up of extensive carbonate sand beaches and occasional basalt outcroppings. Judging from a limited amount of field work, the intertidal communities in these areas appear to be rich with seaweeds and consist of species mentioned previously, including *Sargassum, Turbinaria*, *Padina*, *Galaxaura*, *Tricleocarpa*, a brown alga *Dictyopteris* (limu līpoa) (fig. 50), several species of the red algal genus *Laurencia* (fig. 51), and a surprisingly high abundance of the small calcified green alga *Neomeris annulata* (fig. 52). Overall, these communities appear to be quite diverse.

Figure 48. An unidentified red algal blade with frilly or ruffled red edges at 73-m (240 ft) depth off southwest Moloka‘i.

Summary

The marine environment of Moloka‘i is diverse and includes boulder fields, basalt tidepools, manmade fishponds (which were not surveyed here), shallow carbonate benches, extensive mud flats, coral-dominated reef slopes, macroalgal-dominated deep reefs, and various combinations of all of the above. Each of these different habitat types supports a unique assemblage of marine algae. Both the east and the west coasts are exposed to large waves, have little human impact, and support diverse algal communities in the shallow intertidal and reef-flat areas. The south shore is quite different because it is sheltered from wave action and has an extensive reef flat and many other unique types of habitats. The wide, shallow reef flat is one of the largest continuous shallow-water habitats for the endemic seagrass *Halophila hawaiiana* in Hawai‘i. These areas have been historically productive and have been invaluable collecting areas for numerous species of seaweed or “limu,” which are regularly consumed by the people of Moloka‘i. There is an indication, however, that large portions of these habitats are being overgrown by invasive macroalgal species. The actual cause of this overgrowth remains unclear, but it could be a result of increased nutrients, sedimentation, or perhaps a lack of herbivores in these areas. The deep-water reefs of Moloka‘i harbor numerous seaweed species, many of which are likely new to science. Every effort should be made to preserve the unique marine environments on Moloka‘i and the diversity of species that inhabit them.

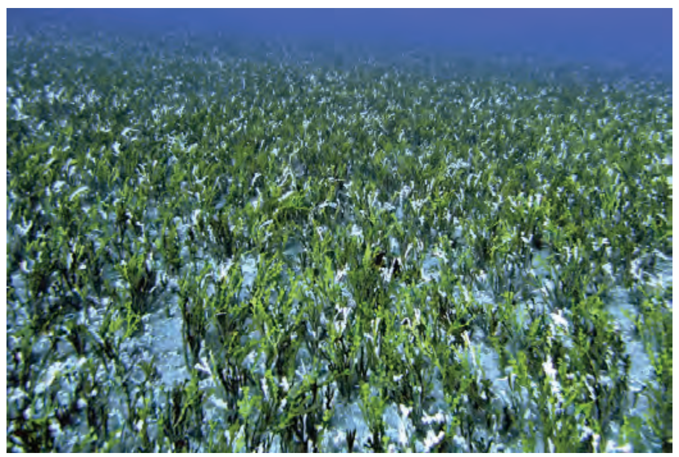

Figure 49. An expansive meadow of the green alga *Halimeda kanaloana*. Such meadows typically occur in soft, sandy sediments and span depths from 10 m (33 ft) to more than 90 m (295 ft).

Figure 50. The brown alga *Dictyopteris* (limu lipoa) can be quite common in the shallow subtidal communities in Hawai‘i, where it often forms extensive beds. This genus is similar to *Dictyota* but has a rib that extends through the middle of each branch, rather than being completely flat like *Dictyota* (see fig. 16). Most species of *Dictyopteris* can grow up to 30 cm (12 in) in height.

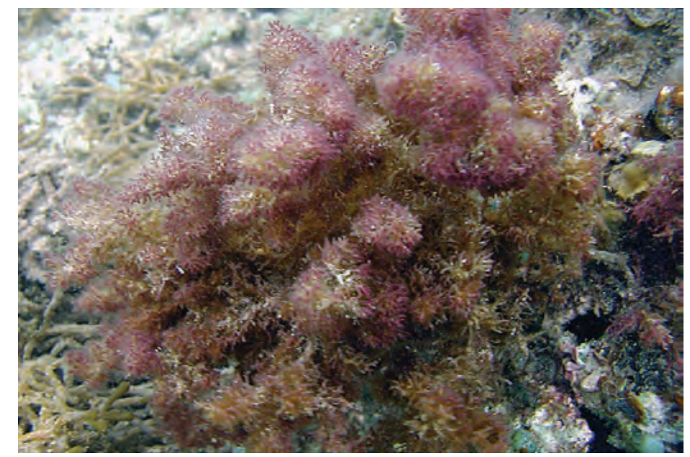

Figure 51. The red alga *Laurencia* is a common component of intertidal communities on rocky or basalt shorelines. There are more than 10 species of *Laurencia* in Hawai‘i, most of which are less than 10 cm (4 in) tall, and species identification can be quite difficult without a microscope.

Figure 52. A dense clump of the calcified green alga *Neomeris* growing along the west shore of Moloka‘i. This species usually grows alone or in clumps consisting of a few individuals less than 2 cm (0.8 in) tall; however, this photograph shows more than 50 individuals growing together.

Suggested citation:

Smith, Jennifer E., Spalding, Heather L., Okano, Ryan, and Smith, Celia M., 2008, The seaweed and seagrass communities of Moloka`i, *Chapter 8 of* Field, M.E., Cochran, S.A., Logan, J.B., and Storlazzi C.D., eds., The coral reef of south Moloka`i, Hawai`i; portrait of a sediment-threatened fringing reef: U.S. Geological Survey Scientific Investigations Report 2007-5101, p. 67-76 [http://pubs.usgs.gov/sir/2007/5101/sir2007-5101_chapter08.pdf].