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# Seaweed resources of the Hawaiian Islands

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**Abstract:** The Hawaiian Islands are located in the central Pacific Ocean and are characterized by tropical waters, volcanic substrata, and isolation. Although many species have been introduced to the Hawaiian Islands, the majority of the seaweeds are considered native to the Hawaiian Islands. Hawaiian seaweeds have been used for food, medicine, and as a source of fertilizer for centuries. Today, seaweeds are used for food, medicine, and other products in the Hawaiian Islands, and there is a growing interest in the cultivation of seaweeds for food, cosmetics, and other products. The Hawaiian Islands are a hotspot for seaweed biodiversity and have a diverse array of seaweed resources, including economically valuable species. However, there are many threats to these resources, including overharvesting, pollution, and climate change. This review provides a synopsis of the Hawaiian seaweed resources and discusses the past, present, and potential future uses of these resources.

**Keywords:** Hawaiian Islands; Hawaiian seaweeds; Hawaiian seaweed resources; Hawaiian seaweed uses.

## Introduction

The Hawaiian Islands are the Hawaiian Islands are composed of a variety of habitats, including coral reefs, rocky intertidal, rocky subtidal, sandy intertidal, and sandy subtidal. The Hawaiian Islands are characterized by tropical waters, volcanic substrata, and isolation. Although many species have been introduced to the Hawaiian Islands, the majority of the seaweeds are considered native to the Hawaiian Islands. Hawaiian seaweeds have been used for food, medicine, and as a source of fertilizer for centuries. Today, seaweeds are used for food, medicine, and other products in the Hawaiian Islands, and there is a growing interest in the cultivation of seaweeds for food, cosmetics, and other products. The Hawaiian Islands are a hotspot for seaweed biodiversity and have a diverse array of seaweed resources, including economically valuable species. However, there are many threats to these resources, including overharvesting, pollution, and climate change. This review provides a synopsis of the Hawaiian seaweed resources and discusses the past, present, and potential future uses of these resources.

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## Introduction

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## Marine environment of the Hawaiian Islands

The Hawaiian Islands are located in the central Pacific Ocean and are characterized by tropical waters, volcanic substrata, and isolation. Although many species have been introduced to the Hawaiian Islands, the majority of the seaweeds are considered native to the Hawaiian Islands. Hawaiian seaweeds have been used for food, medicine, and as a source of fertilizer for centuries. Today, seaweeds are used for food, medicine, and other products in the Hawaiian Islands, and there is a growing interest in the cultivation of seaweeds for food, cosmetics, and other products. The Hawaiian Islands are a hotspot for seaweed biodiversity and have a diverse array of seaweed resources, including economically valuable species. However, there are many threats to these resources, including overharvesting, pollution, and climate change. This review provides a synopsis of the Hawaiian seaweed resources and discusses the past, present, and potential future uses of these resources.

some freshwater lagoons (Abbott 1999; Abbott and Hamamoto 2004). Stakeholders have cited reduction of freshwater flows, nutrient pollution, and the introduction of invasive macroalgal species and abundances (Work Pu, Lima-Ruiz, 2018, pers. comm.).

A second problem, the contamination of coastal waters by input of terrestrial pollutants, has received even more attention. Nearshore waters around the inhabited islands (Hawai'i) have suspect COLIFORM than any other state (USEPA 2013; Wolfert and El-Kadi 2016). Beyond the fecal coliform problem, nearshore waters and coastal ecosystems are exacerbated by the pumice nature of volcanic soils. At Punalu'u Beach, Hawai'i, EP values in macroalgae were traced to inputs of sewage, rather than to agriculture (Megyesi et al. 2016; Allapas et al. 2018). However, in the Kona District, Hawai'i, nitrogen from groundwater provided the most nitrogen to the nearshore waters (Dorse et al. 2010; Amato et al. 2016). Proximity to megacarous fields and water-water injection wells on Maui resulted in higher biomass for three species (Dye, 1994). Although the nutrient pollution problem is well known, the lower benthic species diversity (Amato et al. 2016). Microenzyme pollution has been implicated as a causal factor in phase shifts from coral dominated to macroalgal or turf-dominated ecosystems in waters of O'ahu, Maui, and Hawai'i (Smith et al. 2010; Zhang et al. 2011; Zhang et al. 2012). However, Vermeij et al. (2010) pointed out that on Maui, trophic interactions and spatial competition – rather than nutrient pollution – controlled macroalgal abundance compared to canals. Ecological impacts of nutrient enrichment, may extend to other organisms, such as sea turtles. Van Houtan et al. (2016) investigated prevalence and possible causes of fibropapilloma tumors in Hawaiian green sea turtles (Chelonia mydas Linnaeus, 1758), and suggested that in chronically eutrophic Hawaiian coastal waters, increased consumption of invasive seaweeds could be a factor because these seaweeds store excess nitrogen as arginine, a possible precursor to tumorigenic nitric oxide (Van Houtan 2016). Similar findings were echoed by Work et al. (2016), who argued that the article by Van Houtan et al. (2016) had produced a flawed and not generally applicable hypothesis of a link among seaweeds, arginine, and turtle tumors.

Beach wrack, macroalgal accumulations on land also cause problems associated with increased macroalgal biomass in the presence of invasive species. Stimson and Larkwell (2008) noted that beach wrack of the invasive seaweed Acanthophora spicifera (Vahrwalt) Børgesen, in relation to algae in nutrient availability. When sewage outfalls were diverted in Kāne'ohe Bay, O'ahu, abundance of the prolific S. cyst ernosa declined, however, the decrease in total macroalgal abundance did not continue. Two invasive species, Gracilaria salicornia and Kappaphycus striatum, continued to increase in abundance. The authors of the study, however, hypothesized that dissolved inorganic nitrogen in the seawaters continued to supply sufficient nitrogen to support growth of these species. Thus, impacts from pollution may have persistent effects on macroalgal population.

Climate change is another, and a more complex, conservation issue for the seaweeds of the Hawaiian Islands. These marine seagrasses producing macrofauna, Halimeda macroloba, Halimeda cuneata, Halimeda discoidea, Halimeda kanaloana, Halimeda hawaiiana, and Halimeda copiosa (Ellis & Solander) J.V. Lamouroux, showed a greater change in percent CaCO3 content at an experimental transplant site than at the corresponding control sites (Kuer 2016). The experimental transplant site was located in a shallow, nearshore, coral reef lagoon, and the control sites were located in the potential to shift nearshore macroalgal community structure and to reduce biodiversity in the Hawaiian Islands.

## Community responses to conservation issues

Small, local organizations have started working on their own to explore native species and conserve traditional Hawaiian gathering knowledge. In 2016, at the request of elders in the community, a group of students, from Kamehameha Schools, Bishop Estate, Ka Huaka'i partnered with the Tides Center Project in an initiative to "gather the gatherers" (Mai'ana Ka Nuanoa 2016). Over 30 students and Kupuna Hawaiian representing six Hawaiian Islands came together for 4 days to share knowledge and gather seaweeds. The group, which recently formed group, now known as The Limu Ola, is concerned about the loss of traditional Hawaiian knowledge of limu, the bond in the connection between people and limu, the decline in the health of limu, and the changes in limu abundance and distribution. Kumu Kaleo Kaupu, one of the group's leader, says, "When people stop going to the shore to pick limu, then they lose interest in limu and the limu die." Limu Ola hopes to shift the focus from the loss of limu species to habitat restoration, to share cultural knowledge, and to teach people how to gather seaweeds traditional uses of limu. The group works with schools and communities to set plant-braided raffia cordage with flagging tape to mark seaweeds, and to tie seaweeds to rocks with fishline. In preparation for the Hawai'i Seaweed Symposium Center on O'ahu (Hualalai 2018; Hualalai 2018b). The Limu Ola team was animal gathering to bring together people interested in limu to raise awareness of the importance of



limu to the environment and to pass on knowledge of limu, both primarily by elders to rural, sometimes remote communities. The ability to maintain traditional limu practices is a key factor in the health of the Hawaiian people. Growing abundance of a resource that was once plentiful, Urban development, improper harvesting, alien species, and climate change affect limu around the islands. We do not pointed out that the loss of freshwater spring seawaters and the loss of traditional knowledge of limu and Hawaiian Sudoshoanem (Gracilaria Salicornia), Ma'ole (Chaetomorpha), and manauea (Gracilaria coronopifolia). As gatherers and keepers of the traditional usage of limu slowly age and die, so does their knowledge.

Other conservation organizations based on the Islands of Maui and Lana'i are working on habitat restoration and education. Malu'ulu Limu Restoration, on Maui, is focused on restoring Hawai'i's native limu to maintain a healthy marine ecosystem and to help perpetuate traditional Hawaiian cultural practices (Malu'ulu Limu Restoration 2015). School students meet with the Malu'ulu Limu Restoration team at various sites to enhance their knowledge of the marine environment and to learn how to care for the earth through limu restoration. The Lana'i Limu Restoration Project began as a backyard project in 2015, growing Gracilaria parvispora in 200 l drums (Kamemoto 2016). In 2016, the program shifted to tying G. parvispora and Gracilaria salicornia to ropes and placing them in the ocean. G. e. pa. ra. ra. ra