Management of Forest Ecosystems on Islands The Mangrove in Hawaii as an Alien Species

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Tsutomu ENOKI
University of the Ryukyus

Abstract

Island ecosystems are vulnerable to disturbances. Invasion of an ecosystem by alien species to is one of the most serious problems, especially on islands. Mangroves are the predominanted form of vegetation in the intertidal zone and sheltered shorelines. The Mangrove ecosystem provides a lot of goods and services. In Hawaii, the mangrove was introduced to prevent soil erosion. The mangroves have had many effects on Hawaii, such as changes in water quality and the food chain. To remove the mangroves, trees have been cut down in several areas. In this study, I surveyed Heeia State Park on Oahu Island in order to evaluate the effects of cutting trees on regenerated seedlings. The biomass of seedlings increased after the clear cut. The results of this study indicates that regeneration after clear cutting increases because of the change in light conditions, suggesting that it is necessary to prevent regeneration in order to remove the mangrove from Hawaii.

Keywords: Alien, disturbance, ecosystem, Hawaii, vulnerable

Forest Ecosystems on Islands

Islands are isolated by sea. An island is smaller than the mainland. These are the two most important characteristics of an island. The probability of immigration of organisms decreases with the increase in distance from the mainland. The carrying capacity of organisms decreases with the decrease in the area of an island. Isolation by the sea and a small total area makes the population size and number of species small. This is thought to be a cause of the vulnerability of island ecosystems to disturbances (MacArthur and Wilson 1967, Simberloff 1995).

There are several kinds of disturbances. They include natural and artificial ones. For example, storms, fires, and eruptions are natural disturbances. Logging, pollution, and introduction of alien species are artificial disturbances. Among them, the invasion by alien species is mostly unconscious. Alien species are introduced as food, timber, and a biological control. They are sometimes introduced by accident. The negative effects of alien species on the ecosystem also spread unconsciously. This is called a "silent invasion."

Alien Species in the Hawaii Islands

Numerous exotic species have visited the Hawaiian Islands (Vitousek et al. 1997), and the species are threatening the native Hawaiian forest ecosystems. Because the Hawaii Islands often lack sources of food and forage, colonists, from early Polynesian voyagers to modern government agencies, have promoted plant introduction, including pasture grasses, timber trees, food crops, ornamentals, and sources of fuel and fiber (Muller-Dombois and Fosberg 1998). The history of alien introduction to the Hawaii Islands is divided into two eras. One is the "Polynesian introductions." The other is "post-1778 introductions." The year 1778 is the year that captain Cook discovered the Hawaiian Islands. Before 1778, domestic pigs, dogs, rats, food

plants, kukui trees (*Aleurties moluccana*), and so on, were introduced by Polynesians. The alien, species, however, only affected lowland ecosystems. After 1778, a lot of species were introduced, such as cats, goats, mongooses, birds, and more than 4600 species of plants. The aliens are threatening the environment over the all islands now.

One of the remarkable things is that "natural" Hawaiian biota have been influenced on human. It is almost impossible to remove all aliens from Hawaii. For example, kukui was used for light, canoes, fishing, tanning, leis, catching birds, and as a source of food, medicine, and dye. The trees are easy to see in Hawaii now. Kukui is the official tree of the state of Hawaii and the island flower of Molokai. Many alien species have been perpetuated in the nature and culture of Hawaii.

Along roads on the Big Island, strawberry guava covers the forest edges. This species was introduced for food. The understory of strawberry guava is too dark for other species to regenerate. The strawberry guava itself regenerates by sprouting. Alien species have not only direct affect on an ecosystem, but can also have secondary effects. The replacement of species makes the scale of natural fires increase. One of the mechanisms is as follows: a native species burns relatively easily. However, distribution of each species is not so wide, so the spatial scale of wildfire is small. On the other hand, alien species cover large areas with one species, so in a fire, large areas burn.

Currently, there are several projects to fight against the invasion of alien species in Hawaii. Fences are constructed in a forest reserve to prevent the spread of feral pigs. Introduction of natural enemies of strawberry guava is under consideration. Replacing fire-intolerant alien species with tolerant native species is applied. In addition of these practices, various things should be considered to control the aliens, but the effects of the aliens and their control must also be considered. To decide how to control alien species, research, cooperation, and education are important. Accumulation of scientific data is useful to evaluate the effects of aliens and their control. To apply a control, community, national and international cooperation are necessary. Education is one of the most important components in controlling alien species. People should know what effects the aliens have. Knowledge is a fundamental of alien control.

The Hawaii Ecosystems at Risk Project has ten-point action plan to control alien species in Hawaii.

1) Stop the brown tree snake.
2) Dramatically increase public awareness of alien pest problems.
3) Prevent pest introductions by mail.
4) Prevent pest introductions via aircraft.
5) Prevent pest introductions via shipped cargo.
6) Develop more effective systems to detect, contain, and educate about new pest infestations before they become widespread.
7) Stop the interisland spread of known pests.
8) Ensure stiff penalties for deliberate pest introduction.
9) Clarify which species are prohibited and simplify the permit review system
10) Ensure federal support for Hawaii's pest prevention.

This project covered control the already introduced alien species, preventing the introduction of new species, and also education. The content of this project can be seen on the Web at (http://www.hear.org).

Mangroves as an Alien Species in the Hawaiian Islands

Mangrove Ecosystems

Mangroves are the predominant form of vegetation in the intertidal zone of tropical and subtropical estuaries, lagoons, and sheltered shorelines, and perform a lot numerous functions. The mangrove ecosystem provides timber, fuel, and, habitat for crabs, fish,

and other organisms, improves water quality, and controls soil erosion.

Mangroves are used in several ways. In United Arab Emirates, mangroves are planted to improve the fishery resources. Mangroves are also used for greening in desert. Most of the vegetation in the city is maintained through the consumption of large quantities of fresh water, which is made from seawater using a lot of oil and money. On the other hand, mangroves do not need pure water for growth.

Mangroves in Hawaii

The first introduction of the mangrove into Hawaii was in 1902 (Allen 1998). *Rhizophola mangle* L. (Red mangrove) from Florida was planted on the island of Molokai to prevent soil erosion and supplement the honey flora. The United States Experimental Station and the American Sugar Company introduced it. Now, mangroves are growing on most islands in Hawaii. Strong currents prevent the mangrove from settling. There are a few areas favorable for growing mangroves; however, fishponds, which were constructed by humans, make favorable sites for mangroves to settle. The mangroves have invaded much of the protected shoreline. They were estimated to cover 72% of all estuarine intertidal habitats along Hawaii's coastline in 1977 (U. S. Fish and Wildlife Service 1985).

The characteristics of mangroves in Hawaii are high seedling density and high productivity (Allen 1998, Steele 1999). In particular, the production of reproductive organs is very large. The reasons for this are favorable physical environment, lack of competition from other species, and a low level of herbivores (Steele 1999). The latter two result from the fact that mangroves in Hawaii are an alien species.

The mangroves have many effects on Hawaii. For ecological effects, the mangroves change water quality and the food chain. The concentration of dissolved oxygen decreases in the lower area of mangroves. The replacement of vegetation by mangroves on seashores reduces the area in which waterbirds breed. For socioeconomic effects, the roots of mangroves penetrate and destroy the walls of fishponds. Fishponds are archaeological sites in Hawaii. The mangrove changes waterways and could cause drought and odor.

According to Allen (1998), it takes from $108,000/ha (machinery) to $ 377,000/ha (chainsaws on a floating walkway) to remove mangroves in Hawaii. He also said that the total area of mangroves in Hawaii is less than 1,000ha, and it is possible to remove all the mangroves. However, only cutting them down is not enough to remove the mangroves. After cutting, large number of seedlings grow better than before the cutting. Therefore, I surveyed the effects of cutting on seedlings in Heeia State Park.

Field Study

The research site was a mangrove forest in Heeia State Park on Oahu Island (Fig. 1). Some of the trees on this site were cut down two years ago. To evaluate the effects of cutting trees on the regeneration of seedlings, I established a study plot containing both forested and clear-cut sites (Fig. 2). I surveyed seedlings along three lines from the forest to the clear-cut site. Each line contained nine 1m x 1m subplots. I measured canopy openness at each subplot to evaluate the light conditions. The density, height, and biomass of seedlings were measured.

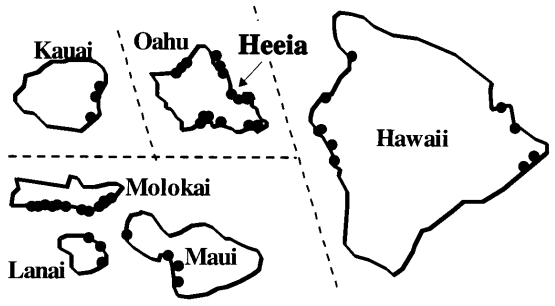

Fig. 1. Approximate locations of known mangrove stands

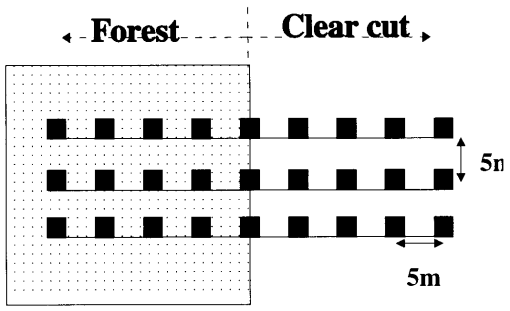

Fig. 2. Location of the sampling plots

The canopy openness increased with the distance from the edge of forest (Fig. 3). The seedling density in the clear-cut site was larger than that in the forest, though the density decreased at 15m from the edge (Fig. 4). The weight of the seedlings increased with the distance from the edge of the forest. The biomass of the seedling also increased with the distance from the edge and reached a plateau at 15m from the edge.

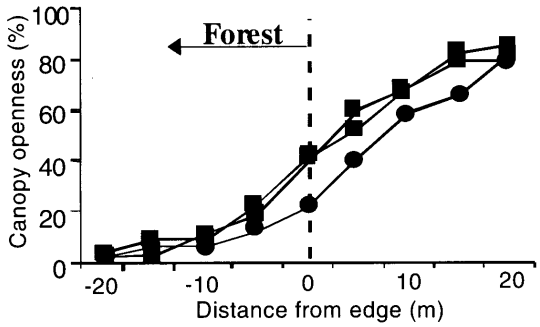

Fig.3. Difference in canopy openness with the distance from the edge.

The results of this field study indicate that regeneration after clear cutting increases because of the change in light condition. In Hawaii, mangroves produced more prolifically than other native mangroves, and there are few herbivores. It is necessary to prevent regeneration in order to remove the mangrove from Hawaii. This discussion is based on the premise of removing the mangrove from Hawaii to recover the native shoreline. However, it is very important to consider whether the mangrove should be removed or not because the value of the mangrove is very variable, and there is little few information about whether the detriments ought weigh the benefits.

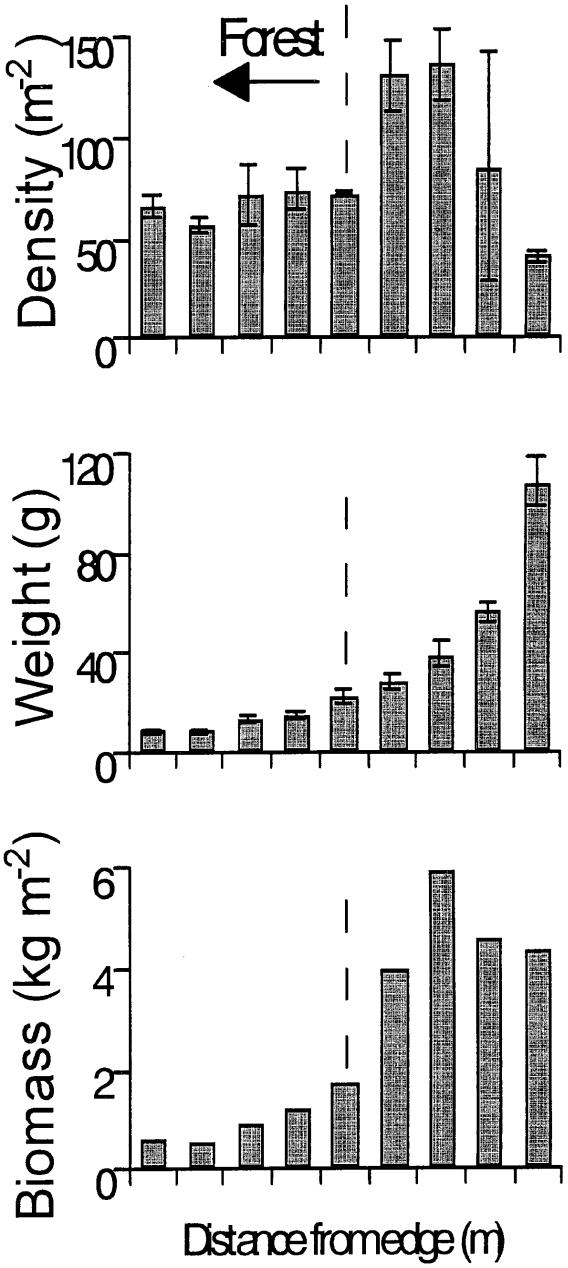

Fig. 4. Differences In density, Individual weight, and biomass of *R. mangle* seedling with distance from edge

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