DRAFT ENVIRONMENTAL ASSESSMENT

Biocontrol of Strawberry Guava by its Natural Control Agent for Preservation of Native Forests in the Hawaiian Islands

State of Hawai‘i

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Prepared for:

State of Hawai‘i
Department of Land and Natural Resources
1151 Punchbowl Street, Room 131
Honolulu, Hawai‘i 96813

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PROPOSING AGENCY:

State of Hawai‘i
Department of Agriculture
1428 South King Street
Honolulu, Hawai‘i 96814

APPROVING AGENCY:

State of Hawai‘i
Department of Land and Natural Resources
1151 Punchbowl Street, Room 131
Honolulu, Hawai‘i 96813

CONSULTANT:

Geometrician Associates LLC
P.O. Box 396
Hilo, Hawai‘i 96721

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Use of State Lands and State Funds

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SUMMARY OF THE PROPOSED ACTION, ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

The Hawaiʻi Department of Agriculture proposes the environmental release on State lands in Hawai'i of a scale insect from Brazil, *Tectococcus ovatus*, for biological control of strawberry guava, *Psidium cattleianum*. *T. ovatus* is a highly specific natural control agent producing leaf galls on strawberry guava that reduce its vigor and fruiting in its native range in Brazil. Strawberry guava exists in balance with other native plants in its native range in Brazil, where it is host to various natural predators and biological control agents. Strawberry guava has no such controls in Hawaiʻi, and their absence contributes to this fast-growing tree's ability to outcompete the native plant species of Hawaiʻi, which have both native and introduced predators. The invasion of strawberry guava into native forests has had devastating effects on the biodiversity, cultural resources, scenic beauty, and watershed values of the native forest. Strawberry guava infestations are also a significant source of agricultural pest fruit flies. Introducing a natural biological control agent will help reduce growth and reproduction of strawberry guava, and thus help "level the playing field," allowing Hawaiʻi's native plants to better compete with the invasive strawberry guava.

Release of the biocontrol agent is proposed on State lands managed by the Hawaiʻi Department of Land and Natural Resources, specifically Forest Reserves and Natural Area Reserves where strawberry guava is invading and causing negative impacts. Initial release of the biocontrol agent is proposed for the Olaʻa Forest Reserve on the island of Hawaiʻi, to be followed by releases in other Forest Reserves and Natural Area Reserves. Eventual occurrence of the insect is expected to extend to invaded forests statewide after distribution by State and Federal agencies. The proposed action requires Plant Protection and Quarantine permits from the USDA, Animal and Plant Health Inspection Service (APHIS) (obtained); a permit for import and liberation of restricted organisms from the HDOA, Plant Quarantine Branch (obtained); and a permit for release and monitoring of the insect on State forest land from the Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife (the trigger for this EA).

Populations of *T. ovatus* are expected to increase to effective levels on the target plant within a few years at release sites. Spread of the insect from the initial release site will occur naturally via wind dispersal and artificially via redistribution efforts by State and Federal agencies involved in strawberry guava management. *T. ovatus* is expected to reduce vegetative growth and fruit and seed production, slowing the spread of strawberry guava over a period of years. The action is expected to have major biological, cultural and economic benefits. Native plant and animal species, including many endangered rainforest species, would benefit greatly due to significant reduction in the competitive ability of strawberry guava relative to native species in Hawaiian forests. This will benefit the biodiversity and ecological values of these forests. Protecting the health and abundance of rare native plants that are severely threatened by strawberry guava will also benefit cultural practices that rely on gathering these plants. Because strawberry guava infestations reduce the quantity of water recharging aquifers, protecting native forests from strawberry guava invasion will benefit watersheds and help maintain supplies of fresh water. Economic benefits in agriculture will ensue from the improved control of pest fruit flies, for which wild strawberry guava is a major source. Biocontrol will also increase the effectiveness of mechanical and herbicidal control in areas where these techniques can be employed.

Although some in the public have expressed concerns about the adverse effects of strawberry guava control, careful analysis of these concerns indicate that few if any adverse impacts are foreseen. In Brazil, *T. ovatus* has never been found on any agricultural crops, only strawberry guava and one closely related plant (*Psidium spathulatum*, an uncommon wild tree found only in southern Brazil). Evidence from extensive host specificity testing involving about 100 related native, commercial, and ornamental species along with observations of the host range of *T. ovatus* in Brazil indicate that this biocontrol agent will attack only the target weed strawberry guava in Hawaiʻi. Modern biocontrol requires rigorous testing. Since 1975, 51 biocontrol species (including natural enemies for the weeds clidemia, banana poka, and ivy gourd) have been introduced to Hawaiʻi without any adverse effects. A biocontrol agent for the wiliwili gall wasp, which has devastated a tree important for both dry forest ecology and cultural uses, was released in November 2008 and is currently being evaluated for success. *T. ovatus* does not kill strawberry guava or taint its fruit. It slows fruit production and spread. The proposed action will impact stands of strawberry guava gradually, allowing more native species to grow back and helping native forests to regenerate. People will still be able to pick fruit and gather the wood, as Brazilians continue to do in their gardens and forests, where the trees are preyed upon by numerous insects. In Brazil strawberry guava is not so rare that people cannot enjoy its fruit, but it is slowed down to a degree that it does not form extensive thickets like it does in Hawaiʻi. Horticultural oils used to control other scale insects can be used to minimize galls on strawberry guava plants around households, if desired. Populations of native birds and other native animals will not decline. Strawberry guava is one of the greatest threats to Hawaiian forest birds and other native animals, because it displaces native plants that provide essential food and shelter for these species. Some non-native animals, such as birds and wild pigs, eat strawberry guava and spread this invasive species, but none is dependent on strawberry guava for its survival. Substantial decrease in the pig population is unlikely, and hunting will not be adversely impacted and may actually benefit, along with hiking, birding and other activities that depend on forest access, from fewer and less dense thickets.

An alternative to the proposed action considered in this assessment is no action. Under this alternative the insect would not be released on State forest land, and management of strawberry guava would likely be limited to existing methods, which involve herbicides, chopping or bulldozing, all of which have large environmental impacts, are impractical over most of the range of strawberry guava, and are expensive in the limited areas where they are practical.

Because *T. ovatus* is host specific on strawberry guava, and the environmental consequences of its release are expected to be highly beneficial to the native forests and agricultural economy of Hawaiʻi, and adverse effects will be very limited, the anticipated determination from this EA is a Finding of No Significant Impact (FONSI).

PART 1: PROJECT DESCRIPTION, PURPOSE AND NEED AND ENVIRONMENTAL ASSESSMENT PROCESS

1.1 Project Description and Location

The Hawaiʻi Department of Agriculture proposes the environmental release in the State of Hawaiʻi of a scale insect from Brazil, *Tectococcus ovatus*, Hempel (Homoptera: Eriococcidae) for biological control of strawberry guava, *Psidium cattleianum* Sabine (Myrtaceae). This invasive weed, locally called waiawī, is a critical threat to native forests and the natural and cultural resources they contain throughout the State of Hawaiʻi. *T. ovatus* is a highly specific insect that is a natural control agent producing leaf galls on strawberry guava in its native range in Brazil.

Gall-forming insects are common but little-noticed in the environment in Hawaiʻi and worldwide. Gall-formers are typically very highly specialized to feed on a single host plant or very narrow range of closely related plant species. In Hawaiʻi gall-formers include native insect species, such as the psyllid *Trioza* that feeds on ʻohiʻa, and the fly species *Phaeogramma lortnocoibon* and *Trupanea*, which feed on *Bidens* (kokoʻolau), and *Bidens* and *Dubautia* (kupaoa), respectively. Gall-formers in Hawaiʻi also include non-native species such as the wasp *Ophelimus* sp. on eucalyptus, the wasp *Josephiella microcarpae* on banyan, mites on hibiscus, the tephritid fly *Eutreta xanthochaeta* on lantana, and two *Procecidochares* species on pamakani. In all cases these insects and their host plants represent stable, host-specific relationships that have evolved together over many thousands to millions of years.

Release of the biocontrol agent is proposed in Forest Reserves and Natural Area Reserves, managed by the Hawaiʻi Department of Land and Natural Resources, where strawberry guava is invading and causing negative impacts. Initial release of the biocontrol agent is proposed for the Olaʻa Forest Reserve on the island of Hawaiʻi, to be followed by releases in other Forest Reserves and Natural Area Reserves. Populations of *T. ovatus* are expected to increase to effective levels on strawberry guava within a few years at release sites. Spread of the insect from initial release sites will occur naturally via wind dispersal and artificially via redistribution efforts by State and Federal agencies involved in strawberry guava management. *T. ovatus* is expected to reduce vegetative growth along with fruit and seed production, decreasing the spread of strawberry guava over a period of years. *T. ovatus* is known in Brazil to reduce strawberry guava vigor by as much as 25 to 40 percent and fruiting by 60 to 90 percent. Just how fast *T. ovatus* will spread following its release is difficult to predict, but populations of the insect are expected to disperse gradually from release sites, mainly carried by wind. *T. ovatus* is not expected to disperse long distances in the wind except perhaps in rare, major wind events. In addition to purposeful releases on strawberry guava, *T. ovatus* may be dispersed through transport of the tiny insects by humans, most likely on infested strawberry guava plants. Release of this biological control agent at one site in Hawaiʻi can be considered equivalent to release over the entire area of the State in which strawberry guava occurs and in which the climate is suitable for reproduction and survival of the insect.

Monitoring will be conducted to determine the rate of insect dispersal and impacts on strawberry guava populations, vegetation change, fruit fly response, and other data. Impacts of *T. ovatus* on non-target species are not expected to occur. However, effects on both strawberry guava and non-target plants will initially be monitored by the U.S. Forest Service, primarily at release sites in native forest plots where density of selected native species will be measured over several years. Releases in experimental plantings of strawberry guava bordered by common guava (*Psidium guajava*) will provide demonstrations of the specificity of *T. ovatus*. Semiannual reports provided to the Hawai‘i Department of Agriculture Plant Quarantine Branch will record all findings regarding non-target species. The U.S. Forest Service also has research in progress to study the interaction of mechanical control (cutting and stump-herbicide) and biocontrol. These monitoring studies will provide guidance on future actions, including consideration of distribution methods, alternate biocontrol agents, and combined methods of treatment for certain areas.

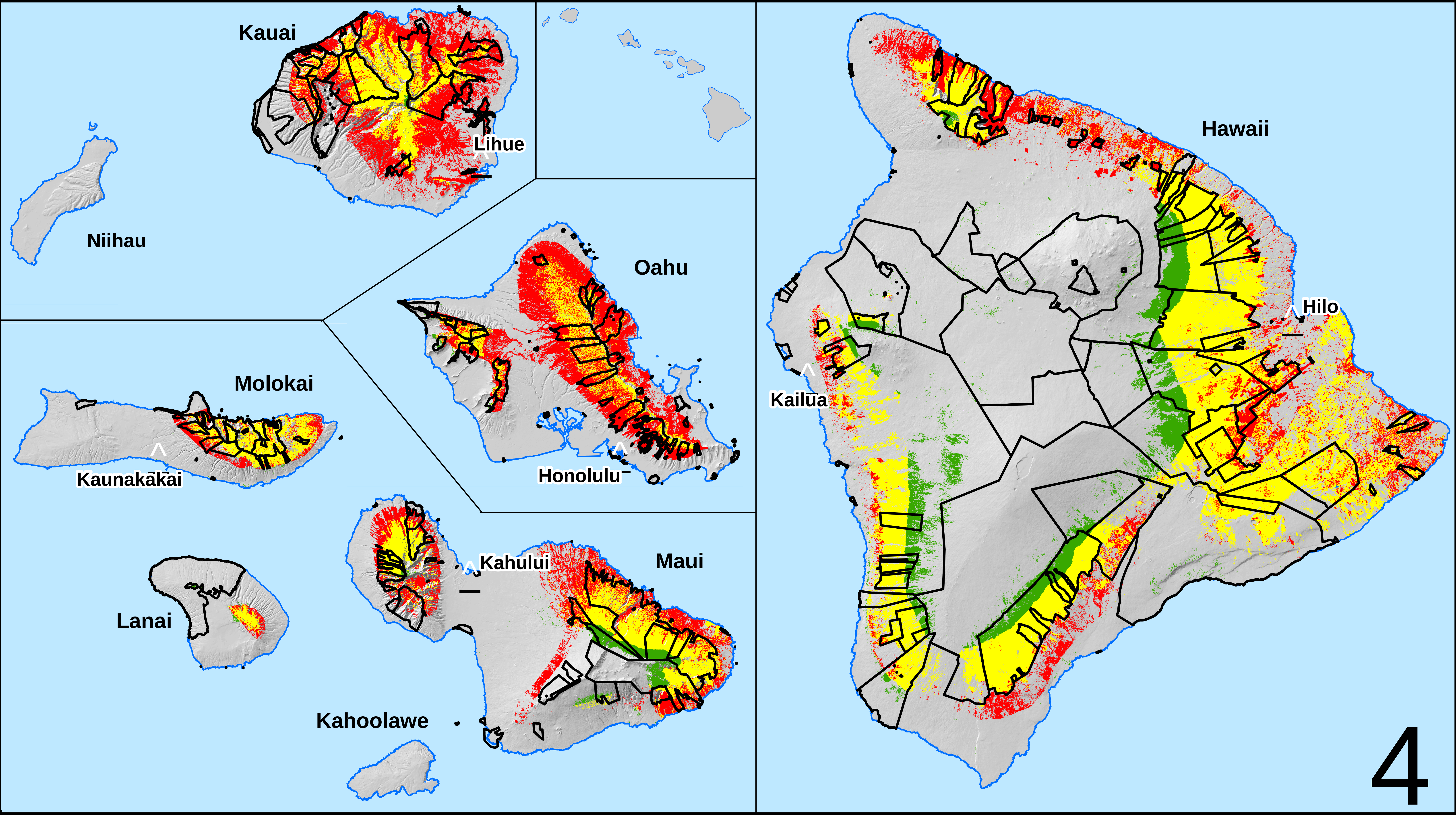
The costs of development of the biocontrol project, begun in 1988 with initial exploration in Brazil and extending to recent pre-release monitoring of strawberry guava in forests where biocontrol is proposed, total about $1.2 million to date. The expenditures were derived from federal and State sources, including $50,000 for monitoring from the Watershed Partnership Program, which is administered by Hawai‘i Department of Land and Natural Resources. The expenditures covered activities such as field research in Brazil, quarantine testing, preparation of permits and petitions, and initial monitoring. The U.S. Forest Service will continue to seek State and federal funding to support its planned monitoring efforts of impacts of strawberry guava and the proposed biocontrol in native forests.

1.2 Purpose and Need

Strawberry guava exists in balance with other native plants in its native range in Brazil, where it is host to various natural predators and biological control agents. Strawberry guava has no such controls in Hawai‘i, and their absence contributes to this fast-growing tree’s ability to outcompete the native plant species of Hawai‘i, which have both native and introduced predators. Since its introduction in the early 19th century, it has become invasive and has gradually expanded into most of the native lowland rainforests, becoming the dominant species over large areas (Figures 1a-c).

The invasion of strawberry guava into native forests has had devastating effects on the biodiversity, cultural resources, scenic beauty, and watershed values of the native forest. The native forests of Hawai‘i are world biological treasures, with over 10,000 native species, the highest rates of endemism in the world, and numerous threatened or endangered species. The biological and water resources of the forest have an important cultural and spiritual dimension for many native Hawaiians, whether they use the forest for hunting, gathering plants for hula or la‘au lapa‘au (medicinal plants), as a source of water for growing kalo, or simply to connect with the pristine natural environment of their ancestors. It also has economic impacts to agriculture, because it serves as a host for massive numbers of fruit flies, and its high growth rates make it difficult and expensive to manage on roadsides, utility corridors, and property boundaries. There is a need to release a host-specific agent for biological control of strawberry guava because chemical and mechanical controls are too expensive and environmentally damaging to apply effectively over large areas, many of which are poorly accessible.

The purpose of establishing *T. ovatus* in Hawai‘i is to reduce growth and reproduction of strawberry guava, thereby limiting this plant’s ability to invade native forests. Introducing a natural biological control agent will help “level the playing field” and allow Hawai‘i’s native plants to better compete with the invasive strawberry guava. *T. ovatus* is expected to reduce impacts of this invasive tree on natural, cultural and economic resources by slowing its growth and spread in native forests, and reducing a key food source of alien fruit fly pests of agriculture in Hawai‘i. *T. ovatus* is expected to reduce vegetative growth and reduce fruit production of strawberry guava, decreasing its spread over a period of years. The action is expected to produce major economic benefits including improved control of pest fruit flies, increased effectiveness of mechanical and herbicidal control, and long-term protection of vulnerable native forest ecosystems from one of their most serious threats.



Strawberry Guava *(Psidium cattleianum)* Estimated Potential Range

0 25 50 Km

0 15 30 Miles

Conservation Areas
-includes state forest reserves, state natural area reserves, national parks, and other other protected areas

Likely dense infestation of Strawberry Guava
-about 495,000 acres
(38% of forested area)

Native forest partially or potentially invaded by Strawberry Guava
-about 680,000 acres
(52% of forested area)

Native forest not threatened by Strawberry Guava
-about 133,000 acres
(10% of forested area)

Strawberry Guava
(Psidium cattleianum)
in East Hawai'i Conservation Areas

Conservation Areas
-includes state forest reserves, state natural area reserves, national parks, and other other protected areas

Likely dense infestation of Strawberry Guava
-about 24,000 acres (10% of forest) in E. Hawai'i conservation areas

Native forest partially or potentially invaded by Strawberry Guava
-about 179,000 acres (76% of forest) in E. Hawai'i conservation areas

Native forest not threatened by Strawberry Guava
-about 13,000 acres (14% of forest) in E. Hawai'i conservation areas

Major Roads

Recorded Locations of Strawberry Guava from 1970'2 ground surveys and 2004 roadside survey.

0 5 10 20 Kilometers

0 4 8 16 Miles

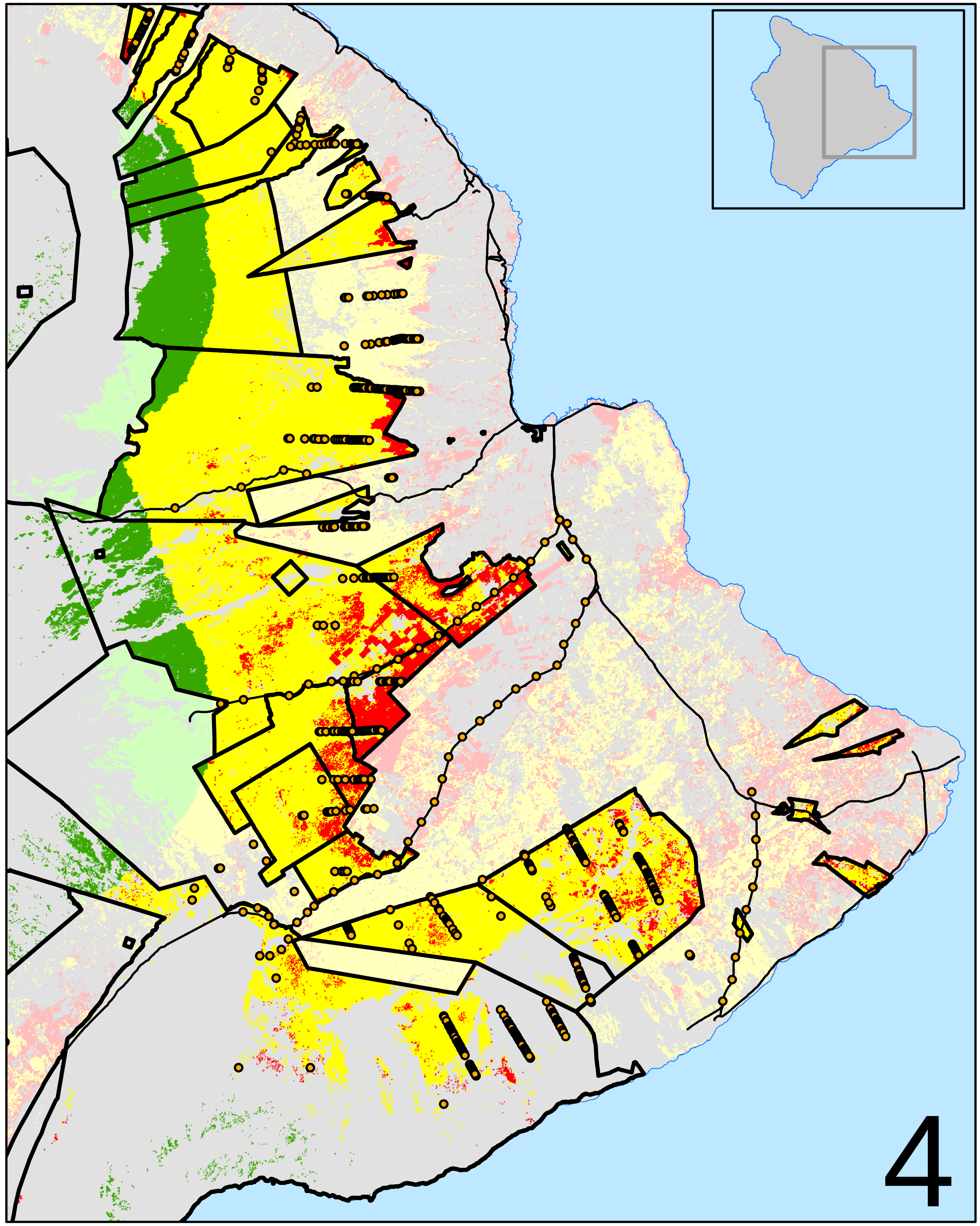
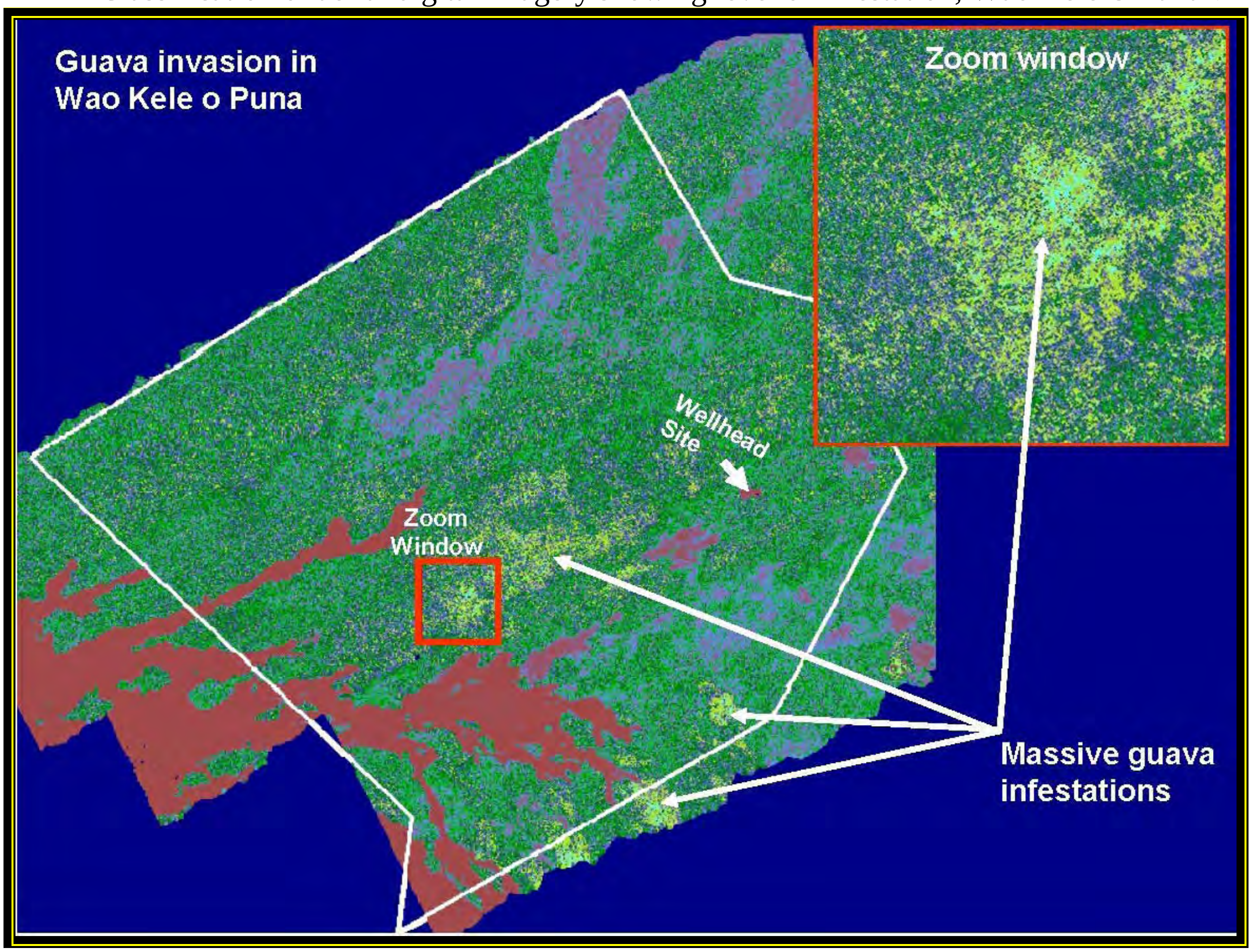


Figure 1c
Aerial Imagery of Strawberry Guava in Wao Kele O Puna

Strawberry guava (dark green) amid ‘ohi‘a (light green/gray) ▲

Classification of aerial digital imagery showing level of infestation, Wao Kele O Puna ▼



Source: G. Asner, Carnegie Institution

1.3 Background

Strawberry Guava in its Native Range in Brazil

Strawberry guava is native to the Atlantic Forest of southeastern Brazil, extending from Espiritu Santo state in Brazil to Uruguay (20-32º S latitude) (Legrand and Klein, 1977; Reitz et al., 1983). It is a common component of *restingas* (sandy coastal plains with scrub vegetation). It also grows inland at elevations up to about 4,000 feet, usually as a successional species in disturbed areas of native forest (Reitz et al., 1983).

In Brazil, strawberry guava is a small tree, 3 to 16 feet tall, rarely growing to 40 feet (Figure 2a). Trees growing within forests have slender, twisted stems and small crowns, whereas open-grown trees have dense, spreading crowns (Hodges 1988). Strawberry guava usually occurs as scattered individual trees and rarely in small clumps (Hodges 1988). Flowering occurs mainly in November-December, and fruits mature during February-April (Reitz et al. 1983). Yellow and red-fruited varieties occur, but the former is much more common. The red-fruited variety may be distributed primarily above 2,300-2,700 feet in elevation (Hodges 1988; Vitorino et al. 2000). At upper elevations in its southern range in Brazil, strawberry guava persists in subtropical conditions, experiencing repeated winter frosts.

Although not planted commercially on a significant scale, strawberry guava has been cultivated for its fruit and ornamentally, and it has been distributed in Brazil beyond its natural range. It is a popular fuel wood (Hodges 1988). *T. ovatus* forms leaf galls similar to those naturally present on some plants in Hawai‘i (e.g., ‘ohi‘a). Its natural presence on strawberry guava in Brazil does not reduce the plant’s usefulness for either fruit or wood (Figure 2).

Figure 2a. Strawberry Guava in a Courtyard in Brazil

Source: USDA Forest Service. These trees in Brazil host the natural predator *T. ovatus* and are still used for fruit.

Figure 2b. Strawberry Guava and Common Guava Side by Side in Brazil

Source: USDA Forest Service. Note leaf galls on strawberry guava (below) and lack of galls on common guava (above)

Strawberry Guava in Hawai‘i

Through purposeful planting of strawberry guava as a fruit tree and ornamental, it has spread in various areas of the world. In many areas of introduction, where no natural biocontrol agents are present, it has become a pest. Beyond Hawai‘i, strawberry guava is recognized as a major threat in native rainforest ecosystems in Mauritius, Reunion, the Seychelles, the Society, Fiji, Norfolk, Palau and Lord Howe Islands (Baijnath et al. 1982, Smith 1985, MacDonald et al. 1991, Cronk and Fuller 1995, Mueller-Dombois and Fosberg 1998).

Strawberry guava was introduced to Hawai‘i in 1825 and is now common on all the main Hawaiian Islands except Ni‘ihau and Kahoolawe between sea level and approximately 4,000 feet in elevation, particularly in areas of moderate to high rainfall (Wagner et al. 1990). Its highest recorded elevations so far are at 4,800 feet near Kulani Prison on Hawai‘i (Keali’i Bio personal communication to Tracy Johnson, USDA Forest Service, 2005) and 5,300 feet at Manawainui on Maui (Art Medeiros personal communication to Tracy Johnson, 2005). Unlike its growth habit in Brazil, strawberry guava in Hawai‘i forms dense thickets that eventually exclude all other vegetation (Figure 3).

The fruit of the strawberry guava is often eaten fresh from the tree by Hawai‘i residents, who appreciate the free bounty of overflowing fruit during the fruiting season. It can also be made into juice and other products (Morton 1987). However, commercially produced “strawberry guava” juice typically is not made from strawberry guava but rather a mixture of strawberry puree and common guava (*P. guajava*) puree. Strawberry guava stems sometimes are used as firewood for smoking meat. One resident reported using the leaves for medicine for diarrhea, a use that is usually reported for leaves of the common guava. The plant is sometimes featured in gardens for its smooth multicolored bark, contrasting with shiny, dark green leaves, along with its toleration of pruning and shaping. Potted plants and seed are sold by some horticulturalists in Hawai‘i.

Total amounts of fruit produced by strawberry guava trees in Hawai‘i have not been previously estimated, but are likely immense, based on the plant’s widespread distribution and the fruit masses it produces in the absence of predators. Based on unpublished data from the USDA Forest Service’s Julie Denslow, strawberry guava trees in East Hawai‘i alone produce more than 400 million fruit per year, or over 9 million pounds. Most of the fruit in dense thickets is borne high on the tree and in the center of inaccessible areas, and is thus not consumable by humans. Pigs and rats consume some of this mass, but probably the majority remains on the ground and rots, serving as food for alien fruit flies. Although research is ongoing, ornithologists have observed various introduced birds such as Melodious Laughing Thrush (*Garrulax canorus*), Red-billed Leiothrix (*Leiothrix lutea*), Northern Cardinals (*Cardinalis cardinalis*), and Japanese White-eyes (*Zosterops japonicus*) utilizing the fruit; in general, native birds do not consume this fruit, and the prevalence of strawberry guava is one more factor that disadvantages native versus introduced birds in the lowland rainforest (Patrick Hart personal communication to Ron Terry, 2009).

Figure 3. Strawberry Guava Thicket in Hawai'i

Source: J. Jeffrey. Strawberry guava forms dense thickets that overwhelm and choke out native species.

Effects of Strawberry Guava on Native Forest Ecology

In the words of The Nature Conservancy, a non-profit organization that has been protecting habitat throughout Hawaiʻi for many decades:

> Hawaiʻi's native ecosystems once extended from the mountains to the sea. Today, the vast majority of Hawaiʻi's native plants and animals find refuge in the upland forests, in large native landscapes scattered throughout the islands. The Islands' native forests are among the world's biological treasures, sheltering more than 10,000 native species – more than 90% of which are endemic or unique to these islands. Hawaiʻi has almost as many types of native forest as there are U.S. states, including the nation's only tropical rain forests. ʻŌhiʻa lehua and koa are the dominant forest types but all total, there are 48 different native Hawaiian forest and woodland types and more than 175 different species of native trees, the vast majority of which are found nowhere else in the world. But today, for all their biological richness, these forests are among the most endangered in the world. Hawaiʻi has already lost half of its natural forest cover. Currently, more than one-third of the plants and birds on the U.S. Endangered Species List are from Hawaiʻi. When spiders, snails, and insects are included, nearly 60% of Hawaiʻi's total native flora and fauna is endangered, by far the highest percentage of any state. Destruction and the loss of forest habitat are the primary causes of species decline."
> (http://www.nature.org/wherewework/northamerica/states/hawaii/forests/)

The loss of ecosystems and the species they contain is biologically unfortunate not only for their own sakes but also for potential benefits to science and medicine that may never occur if they are not sufficiently studied before they are lost.

Over time, more than 900 nonindigenous plant species have become naturalized in Hawaiʻi, and almost 100 of them compete very strongly with native species or even completely alter ecosystem processes that change entire communities (Vitousek and Walker 1989). Strawberry guava is one of the most invasive of these species. It forms dense thickets up to 30 feet high, a growth form that suppresses native species, including many that are rare, threatened or and endangered. Because of these characteristics, it is considered one of the state's most disruptive alien weeds (Hosaka and Thistle 1954, Smith 1985, Huenneke and Vitousek 1990, Wagner et al. 1990, Loope 1998).

Strawberry guava is one of the principal threats in the crisis facing the biodiversity of Hawaiian forests on all islands, which has value for not only ecological but also cultural reasons. Without some form of control, the effects of strawberry guava's spread on the biodiversity, cultural and watershed values of the native forest in Hawaiʻi are likely to be devastating.

The Nature Conservancy has long advocated that biocontrol is ultimately the only hope for combating the choking effects of this invasive species. In the 1991 "Element Stewardship Abstract" for this species, TNC said:

> “Strawberry guava is a very serious habitat-disruptive pest in many parks and preserves in Hawaii because of its tendency to form mono-specific stands…. Prolific fruiting, shade tolerance, clonal regenerative strategy, tolerance of heavy litter fall, and possible allelopathic effects contribute to the success of this species. Removal of feral pigs is the sine qua non and first step of successful management of strawberry guava because pigs disperse prodigious quantities of seed. This must be followed by manual, mechanical, and chemical control measures. These have proven successful when tested on a small scale, and recruitment is low in pig-free intact forest, even with dispersal into the treated area from densely infested adjacent areas. Biological control is the long-term management solution to strawberry guava, and the prospect of locating highly specific biocontrol agents is cause for optimism about the future of biological control for this pest. Clarification of the recovery process is the single most important monitoring need” (http://www.imapinvasives.org/GIST/ESA/esapages/psidcatt.html)

Effects of Strawberry Guava on Cultural Resources

Strawberry guava infestations may severely impact cultural resources, primarily by degrading the integrity and diversity of native forests and outcompeting and eventually eliminating the rare plant species they contain. Many of the native trees, herbs, and ferns in the forest provide flowers, leaves, wood, and sap for products such as hula implements and decoration, la‘au lapa‘au (medicinal plants), dyes for kapa, and countless other traditional products. The relationship is far more than simple exploitation of natural resources; in the traditional Hawaiian viewpoint, the natural and cultural, and the physical and spiritual, are not separate, but an integrated whole. The upland forests, now some of the last refuge for native Hawaiian plants and animals, were once considered the dwelling place of the gods. These wao akua regions were sacred.

Taking care of the land, or malama ‘aina, therefore helps sustain the culture, and the integrity of the ahupua‘a, the forests and the watersheds from mauka to makai, is a critical part of this care. It is for this reason that nurturing outposts of at least limited biological integrity, such as Wao Kele O Puna, now in the care of the Office of Hawaiian Affairs, have been so important to Hawaiian cultural practitioners. If Wao Kele O Puna, along with the other lowland and mid-elevation rainforests of the Hawaiian Islands, degrade into a virtual monoculture of strawberry guava, far more than biological diversity will be lost. Chants and mele that celebrate the sights, sounds and aromas of the forest will have meanings that can no longer be physically experienced. Although foreign woods and foliage can substitute in traditional crafts, at some deep level the power and essence of these products will be diminished.

Effects of Strawberry Guava on Agriculture

Strawberry guava is also a wild host of fruit flies, including the oriental fruit fly and Mediterranean fruit fly, which cost taxpayers and farmers millions of dollars annually in quarantine and eradication efforts (Vargas et al. 1983a&b, Vargas et al. 1990, Harris et al 1993, Kaplan 2004). Attempts at management of fruit fly pests in Hawai‘i are severely constrained by the abundance of fruiting strawberry guava (Vargas and Nishida 1989, Vargas et al. 1995). According to Roger Vargas, a research entomologist with the U.S. Department of Agriculture, “Working with farmers on the Hawai‘i Fruit Fly Area-Wide Pest Management Program, consistently, with almost every crop we looked at – papaya, mango, cherimoya, and lychee, for example – the number-one problem was the impact of strawberry guava” (Conservation Council for Hawai‘i 2009).

The potential for strawberry guava to sustain fruit flies and ruin other agricultural crops is well known in other locations. For example, the Caribbean Fruit Fly-Free Protocol is a body of regulations under which fresh Florida citrus fruit may be certified free of the Caribbean fruit fly and shipped to those domestic and foreign markets that have established regulations for this pest (http://www.doacs.state.fl.us/onestop/plt/cfffprotocol.html). Japan, Bermuda, and the states of California, Hawai‘i, and Texas have accepted this certification protocol, thereby eliminating the need for post-harvest treatments of citrus fruits. Part of the protocol involves having the crops located at least 1.5 miles from strawberry guava, whether wild or within the landscape of a residence.

Current Extent and Future Spread of Strawberry Guava

The current extent of areas in which strawberry guava is adversely affecting the native forest is already significant, as land managers and biologists in Hawai‘i know well. Measuring the exact scale of the infestation is difficult. Figure 1c, above, provides imagery of the Wao Kele O Puna tract on the Big Island, which is owned by the Office of Hawaiian Affairs and managed for its natural and cultural resources. Monoculture stands are easily detectable on normal air photographs, but finding and estimating the extent of strawberry guava beneath a canopy of overhanging trees requires advanced technology. The Carnegie Airborne Observatory carries these instruments on a small airplane whose sensing penetrates the forest canopy to create a kind of “regional CAT scan of the ecosystem”, mapping the forest’s 3-D structure and identifying species. According to the technique’s developer, Greg Asner, “Invasive tree species often show biochemical, physiological and structural properties that are different from native species. We can use these ‘fingerprints’ combined with the 3-D images to see how the invasives are changing the forest” (*Stanford Report*, March 19, 2008).

Although difficult to measure, geographer Jon Price evaluated the extent of strawberry guava in conservation areas through a combination of methods, the statewide results of which are shown in Figure 1a. Reconnaissance by many scientists has demonstrated that there is a very high rate of infestation in lowland alien forests, which are colored red on Figure 1a. At higher elevations are areas that are infested to varying degrees but for which more information is needed, either through the type of aerial imaging referred to above or through laborious ground survey. These areas, colored yellow on Figure 1a, have the potential to become heavily infested. For the Big

Island, results of botanical surveys conducted during the 1970s as part of the Hawaiʻi Forest Bird Survey and road surveys 30 years later provide ground truth data that indicate that many of the potential areas already contain light to dense infestations of strawberry guava ("hits" during the survey are shown as orange circles on Figure 1b). Areas that appear to be too high in elevation for strawberry guava to significantly affect the forest are shown in green. Although it is fortunate that strawberry guava does not infest these high elevation areas, it is notable that most of the threatened and endangered plant species are found at the lower elevations where strawberry guava is a threat.

The problem is likely to grow in magnitude and severity. Strawberry guava continues to expand into relatively pristine native forest areas, although it has spread so widely in Hawaiʻi that its future impacts are expected to consist largely of filling-in areas where it has reached already (Jacobi and Warshauer 1992). Growth rates of strawberry guava in native forests are very high: at 3,000 feet on Hawaiʻi island, average annual increases of over 12 percent in stem density and 9 percent in total basal area have been measured (Julie Denslow, unpublished data). Ecologists have examined the characteristics of the native forest and strawberry guava and envision that without large-scale control efforts, strawberry guava may occupy most of the lowland rainforests of the State. Based on habitat characteristics of sites of existing infestations, strawberry guava has the potential to invade and heavily infest an additional 680,000 acres in conservation lands, and in addition, large areas of private non-conservation lands, where strawberry guava may interfere with forestry, agriculture, archaeological preservation, or other purposes.

Experiences of Land Managers and Field Biologists

Many land managers and working biologists around the State deal with strawberry guava's threat to the endangered plants, animals and ecosystems in their care on a daily basis. Their experiences provide perspective on the ubiquity and magnitude of the problem, as illustrated in these quotes compiled by the U.S. Forest Service:

> "I am a State wildlife biologist for Maui Nui District - I see every day I am in the field doing work in the mountains of Lanaʻi, Molokaʻi, or Maui the tremendously urgent need for biocontrol of strawberry guava. I am certain it is one of the very worst of habitat altering, invasive weeds to ever get a foothold in Hawaiʻi."
> *Dr. Fern P. Duvall, State Wildlife Biologist*

> "The National Park Service and other land managers in Hawaiʻi need more tools to prevent strawberry guava from invading and displacing native forests as densities increase into *P. cattleianum* monocultures. Considerable effort in mechanical and chemical control has been expended by Hawaiʻi land managers over the last 20 plus years and still the invasion footprint and native species displacing monoculture formations of strawberry guava are increasing. Mechanical and chemical control can not keep up with the invasion of *P. cattleianum.*"
> *Steve Anderson, Program Manager for Vegetation, Haleakala National Park.*

“Here in West Maui I have witnessed first hand how strawberry guava *(Psidium cattleianum)* can displace native watersheds with single species monotypic stands, displace endangered species habitats, render vast sections of land susceptible to erosion, exhibit broad habitat preferences, spread to the most inaccessible areas, and advance steadily from low elevations toward the pristine forested core of our lands. Since its introduction to the islands in 1825, strawberry guava has grown to become a dominant species within roughly 2-5 thousand acres of West Maui’s Forest Reserve and adjacent conservation lands. Currently strawberry guava is abundant in many places in West Maui up to 2,000 feet elevation, has strong satellite populations up to 3000 feet and is know to exist over 4,000 feet in elevation. The summit of the West Maui Mountains at Pu‘u Kukui stands at 5,788 feet and strawberry guava has been known to grow in elevations in excess of that on other islands. Given enough time and left unchecked it seems entirely possible that strawberry guava could consume vast expanses of the watershed. It seems further evident in my experience that this is also true statewide.
Christopher Brosius, West Maui Mountains Watershed Partnership Coordinator

“The u‘au or Hawaiian Petrel will probably become extinct because the habitat of the main breeding population which exists on Lana‘i is slowly being destroyed by the strawberry guava. The petrel nests in uluhe on steep hillsides, but strawberry guava is successfully colonizing, and its roots are so dense that the petrels can no longer dig their burrows between them.”
Dr. David Duffy, PCSU Unit Leader, UH Manoa

“Much of my work in the past decade has been trying to foster the development of a sustainable koa forest industry in Hawai‘i. The koa forest at lower elevations in East Hawai‘i is being rapidly invaded by strawberry guava. Currently, harvesting of koa in these forests is unsustainable, because dense strawberry guava regeneration overwhelms the koa regeneration. Although it has been well documented that in natural forests koa can regenerate healthy stands naturally following disturbances and harvests, harvesting in forests invaded by strawberry guava just leads to thickets of the weed. There is too much guava to practically control by chemical or mechanical means. Biocontrol is the only solution. I am working with several large private landowners currently who would like to begin sustainable forestry projects in low-elevation koa forests in East Hawai‘i, but the stumbling block is the presence of the strawberry guava.”
Dr. J.B. Friday, Forester, UH Manoa

“As a technician in conservation efforts throughout the Hawaiian Islands for the past ten years, I have spent countless hours cutting and applying herbicide to strawberry guava growing in endangered species habitat. In the Ko‘olau Mountains, where our agency was responsible for the protection of a number of highly endangered, rare, endemic plants, we were extremely discouraged by the waiawī’s ability to resprout from cut saplings. We would helicopter into remote areas, spend three days camping, spending the entire time “killing” waiawī --but when we returned to follow up, it was like we had done nothing! The large piles of cut stems sprouted roots and new growth, and the forest floor was a

carpet of keiki waiawī! We spent thousands of dollars, used gallons of polluting herbicides, and were unable to maintain even a stand-off with this invasive weed. Endangered plants are unable to coexist with this weed--in the darkness under a stand of strawberry guava, NOTHING else grows."
Springer Kaye, UH Hilo TCBES graduate program

"I regard strawberry guava as perhaps having done more destruction to endemic forest species in the state of Hawai'i over the past century than any other invasive plant. We on Maui are so committed to stopping the as yet very limited invasion of *Miconia calvescens.* We recognize, however, that strawberry guava has very similar impacts to miconia but is far beyond mechanical and chemical control and is much more widespread than miconia and still spreading."
Dr. Lloyd Loope, USGS Pacific Island Ecosystems Research Center Haleakala Field Station

"I reside in an older lowland forest kipuka where several dense stands of mature lama *(Diospyros sandwicensis)* can be found among towering 'ohi'a lehuas. Last year, at least twelve mature lamas on the property, which were 30-40' tall and up to 2' in diameter, died suddenly. I contacted J.B. Friday and Dr. Scott Nelson, both of CTAHR, who determined that an infestation of strawberry guava was probably to blame. They believe that during this period of drought, the massive surface roots of the strawberry guavas may have deprived these lamas of crucial soil moisture and nutrients, causing their deaths. Since then, I have worked with the property owners to eradicate this noxious weed. However, even on eleven acres, this is proving to be a daunting task.
Mitzi Messick, landscape designer

"My own experience and publications have shown that strawberry guava is a highly invasive species that is actively excluding native species and is altering the way that Hawaiian forests function. I am finding strong evidence that the shade produced by strawberry guava and other species is impeding native species regeneration. I believe the consequences of inaction will lead to wholesale transformation of Hawai'i's low and mid-elevation wet forests into alien-dominated forests that function very differently in terms of providing nutrients, water, and other ecosystem services. This alteration of function will lead to greater invasion of plants and animals in Hawai'i's forests and a loss of native biodiversity."
Dr. Rebecca Ostertag, Ecologist, UH Hilo

"In the past three decades I have seen *Psidium cattleianum* go from being a serious invasive to becoming a biological catastrophe for 'ohi'a forests. They have gone from being rampant invaders, to completely replacing native forest, including the forest floor, the understory, and soon will replace the dwindling canopy in many areas. I don't see much future for wet forests, where strawberry guavas have invaded, unless there is some sort of control."
David Paul, President Big Island Native Plant Society

> "As the Maui District Endangered Species Research Specialist I am engaged in work to enhance Hawaiian petrel *(Pterodroma sandwichensis)* habitat on the island of Lanaʻi. I see strawberry guava as the most significant threat to the continued viability of the Hawaiian petrel colony on Lanaʻi. We are using manual control methods, and herbicide applications to address the invasion of this plant. We need every available tool if we are to preserve Lanaʻihale as a petrel colony and as a watershed. The scope of the problem is so great that without biocontrol to add to our tool bag we face a nearly impossible task of habitat restoration."
> *Jay Penniman, Maui District Endangered Species Research Specialist, Hawaiʻi DLNR*

> "As a bird lover and wildlife biologist who has worked for the state and federal governments, I've learned the harm this plant can do and understand that in order to control it over so many thousands of acres a tool like biological control is badly needed. I'm especially concerned that this guava is destroying the habitat of some of our native birds, especially the native honeycreepers that rely on native trees and shrubs to supply them with nectar, which guava cannot do. Strawberry guava also seems to be suppressing the regeneration of ʻohiʻa trees. Nearly all the native forest birds need ʻohiʻa trees to nest in, but they do not build their nests in strawberry guava because it doesn't afford the same degree of shelter."
> *Dr. Thane Pratt, USGS Pacific Island Ecosystems Research Center Kilauea Field Station*

> "The goal of our partnership is the protection of forested watershed on Kohala Mountain. Strawberry guava (*Psidium cattleianum)* is one of our priority weeds…We have seen the speedy spread of this weedy tree not only near areas of human disturbance, but also into the forest, where it is able to establish in closed canopy forest areas far from people. In these environments, it has the capacity to completely overtake native trees and to change the structure and function of the native habitat. Additionally, it is expensive and difficult to control with mechanical and chemical means."
> *Melora Purell, Coordinator, Kohala Watershed Partnership*

> "My observations over the last 38 years indicates the dying out of native forests in many areas of Oʻahu due to the continued spread of strawberry guava and other weeds, among other factors…Strawberry guava leaf litter also is extremely poor habitat for the native terrestrial snail species. Wherever strawberry guava has spread, the native terrestrial snails have declined or died out."
> *Dr. Daniel Chung, Biologist, former Nature Conservancy and Bishop Museum*

Modern History of Biocontrol in Hawaiʻi

Many people have the mistaken impression that a sugar plantation owners ill-fated import of mongooses to control rat populations is a typical example of biocontrol. Actually, biocontrol is the careful and scientific introduction of an organism to control the growth or spread of an invasive organism. In the case of invasive plants, these biocontrol agents are natural enemies of a plant in its home range that feed on or damage a part of the plant, making it easier to manage. Biocontrol can reduce the abundance of an invasive species gradually but cannot eliminate it completely. Whereas chemical and mechanical approaches require perpetual and often expensive maintenance, can inflict undesirable side effects, and are ineffective in areas of inaccessible terrain, biocontrol offers a cost-effective and long-lasting tool to control invasive species in natural habitats. Biocontrol is an accepted management practice in over 100 countries, including the United States. Modern biocontrol involves extensive research to identify predators that are specific to a given invasive plant or animal, including years of laboratory and field testing of the potential biocontrol agent under rigorous protocols (Wapshere 1974, Balciunas and Coombs 2004). Only at the end of this process do state and federal agencies carefully consider a proposed release and approve permits, as described in Section 1.4 for *T. ovatus*.

The long history of biocontrol of invasive species in Hawai‘i dates back to the 1890s, when the Territorial Board of Agriculture and Forestry began looking in Mexico for insects and diseases of lantana (*Lantana camara*). Initial introductions of lantana enemies in 1902 were followed in the 1950s and 60s by additional species. The eventual result was establishment of more than 20 enemy species which varied in effectiveness depending on environmental conditions but led to successful suppression in many areas (Davis et al 1992). This example illustrates that for widespread problems and difficult species, multiple agents may be necessary. Another early success story was biocontrol of prickly pear cactus (*Opuntia* spp.). Over 66,000 acres on Parker Ranch alone became infested with the cactus. By 1965, less than 8,000 acres remained infested, thanks to three introduced insects and an accidentally introduced fungal disease. These enemies still occur on scattered cactus today, illustrating that even dramatically successful biocontrol efforts do not “wipe out” the target species, but rather suppress it to acceptable levels. Hamakua pamakani (*Ageratina riparia*) is an aggressive, fast-spreading, noxious weed that became an extreme pest in Maui and Big Island range lands during the first half of the 20th century. By 1960, it was crowding out native plants in Hawai‘i Volcanoes National Park. After introduction of insects from Mexico and a foliar fungus from Jamaica, Hamakua pamakani was well controlled (Davis et al 1992).

In the Hawaiian Islands, 708 biocontrol agents were released between 1890 and 1999, of which 286 became established. Most of these introductions helped control their target species, which were mainly insect pests of agriculture (Reimer 2002). About 60 biocontrol agents were established during this period targeting 20 invasive plant species (some shown in Figure 4). In the early years, some biocontrol agents also attacked non-targeted pests or in some cases native and/or beneficial species. As the rigor and oversight of scientific testing improved, so did the safety of biocontrol introductions. Before 1944, when the Board of Agriculture started reviewing applications, only 54.7 percent of the agents were host specific. Between 1944 and 1975 that percentage increased to 77.4. Since 1975, when a group of three expert committees started reviewing all applications, host specificity has been 100 percent (Reimer 2002).

As illustrated by the following three cases, while biocontrol by itself may not completely solve the problems with any given invasive species, modern biocontrol efforts in Hawaiʻi have been remarkably successful:

- <u>Koster's curse</u> (*Clidemia hirta*) is a shade-tolerant weed often found along trails and other areas in the forest. Originally from tropical America, its seeds are spread by birds (Motooka et al. 2003). In some areas it forms dense tickets in the lower herb layer, choking out natives. Biocontrol has made some inroads against this pest. In open ranchland, the thrips *Liothrips urichi* has helped control it substantially. Although the leaf spot fungus (*Colletotrichum gloeosporioides*) has helped to some degree, and various insect species are under study, control in lowland rainforest requires additional work (Conant 2002).
- <u>Ivy gourd</u> (*Coccinia grandis*) can densely blanket vegetation in residential neighborhoods and farms, and the heavy vines hanging on electrical and telephone lines pose severe problems for utility companies. In addition, ivy gourd fruits are a host for the agricultural pest melon fly (*Bactrocera cucurbitae*). Several insect biocontrol agents from Kenya have been introduced into Hawaiʻi for this pest (Chun 2002). Impacts are now evident from a clearwing moth released in 1996, *Melittia oedipus,* whose larvae bore into the mature vines and roots, and a small leaf mining weevil, *Acythopeus cocciniae*, released in 1999. There is noticeably less ivy gourd in many locations around the State, including Kona (Pat Conant personal communication to Ron Terry, 2009).
- <u>Banana poka</u> (*Passiflora tarminiana* [formerly *mollissima*]) is an aggressive vine from South America that smothers mid- to upper elevation native forests with dense mats of stems and foliage which can damage even large trees. Banana poka is a threat to koa forestry because the prolific vines block natural regeneration of this valuable native tree. Beginning in the early 1980s State and Federal entomologists and plant pathologists explored Colombia, Ecuador and Venezuela in search of potential biocontrol agents, and several agents were imported to Hawaiʻi under quarantine for testing. After testing, some insect species were released but had little effect. A fungus, *Septoria passiflorae*, was released in 1996 and worked well in the upper Laupahoehoe area of the Big Island, assisted perhaps by a long drought (Trujillo et al. 2001, Smith et al 2002; Steve Bergfeld personal communication to Ron Terry, 2009). Scientists continue to investigate ways to use biocontrol in areas where banana poka remains a major pest, including Kula Forest Reserve and Polipoli State Park in Maui.

In summary, Hawaiʻi's native ecosystems and the plants and animals they contain, as well as agriculture and grazing, have benefited enormously from successful biological control efforts. Over 50 biocontrol agents have been released in Hawaiʻi against insect and weed targets since strict regulatory processes were established in the 1970s, and none has switched hosts to non-target species or become invasive themselves (Reimer 2002).

Figure 4. Invasive Plants Managed Using Biocontrol in Hawai'i

Clockwise, from Upper Left: Lantana, Prickly Pear, Clidemia, Ivy Gourd, Banana Poka and Pamakani. (All images from Kim and Forest Starr)

1.4 Environmental Assessment Process and Environmental Permits

Basis for Environmental Assessment

This Environmental Assessment (EA) was prepared in accordance with Chapter 343 of the Hawai‘i Revised Statutes (HRS) by the Hawai‘i Department of Agriculture, which is the proposing agency, with assistance from the U.S. Department of Agriculture (USDA), Forest Service, Institute of Pacific Islands Forestry (herein called the U.S. Forest Service). As the release would take place on State land under the control of the Hawai‘i Department of Land and Natural Resources (DLNR), that agency is acting in the context of Chapter 343, HRS, as the approving agency. Chapter 343, HRS, along with its implementing regulations, Title 11, Chapter 200, of the Hawai‘i Administrative Rules (HAR), is the basis for the environmental impact assessment process in the State of Hawai‘i. According to Chapter 343, an EA is prepared to determine impacts associated with an action, to develop mitigation measures for adverse impacts, and to determine whether any of the impacts are significant according to thirteen specific criteria. Part 4 of this document states the anticipated finding that no significant impacts are expected to occur; Part 5 lists each criterion and presents the findings by the approving agency. If, after considering comments to the Draft EA, DLNR concludes that, as anticipated, no significant impacts would be expected to occur, then it will issue a Finding of No Significant Impact (FONSI), and the action will be permitted to occur. If DLNR concludes that significant impacts are expected to occur as a result of the proposed action, then an Environmental Impact Statement (EIS) will be prepared.

Previous Environmental Documentation

In May 2005, the U.S. Forest Service initially proposed the release of *T. ovatus* to slow the spread of the invasive strawberry guava in Hawai‘i. The proposal followed a decade of laboratory and field experiments conducted in both the insect’s native Brazil and in quarantine facilities in Hawai‘i. A federal EA was prepared by the USDA Animal and Plant Health Inspection Service (APHIS). The public was notified through local newspaper articles, research updates dispensed as hard copies and on the Institute of Pacific Islands Forestry website, occasional presentations to various stakeholder groups, public meetings sponsored by the Hawai‘i Department of Agriculture as part of the permitting process, and advertisement of the availability of the federal EA in local newspapers. Following review by State and Federal regulators (a process which lasted 3 years), permits for the release were issued in April 2008.

Compliance with the State of Hawai‘i EIS law, Chapter 343, HRS, and its implementing regulations at 11 HAR 200, was triggered by the proposed release of *T. ovatus* on forest lands managed by the Hawai‘i Department of Land and Natural Resources. An additional EA attempting to address Hawai‘i EIS law was prepared by the U.S. Forest Service and published on April 23, 2008. Analysis by the U.S. Forest Service and DLNR indicated that this first State of Hawai‘i Draft EA had an erroneous listed applicant and failed to adequately encompass the scope of the action or address all pertinent impacts; it was decided to completely withdraw this EA. The original State of Hawai‘i EA was withdrawn and the current document was prepared, with a new (and correct) proposing agency, a new title and scope, and expanded consideration of impacts.

Environmental Permits

The proposed action requires Plant Protection and Quarantine permits from the USDA, Animal and Plant Health Inspection Service (APHIS) (obtained April 4, 2008); a permit for import and liberation of restricted organisms from the HDOA, Plant Quarantine Branch (obtained April 7, 2008); and a permit for release and monitoring of the insect on State forest land from the Hawaiʻi Department of Land and Natural Resources, Division of Forestry and Wildlife (the trigger for this EA).

Conditions for environmental release of *T. ovatus* in Hawaiʻi have been established by the Hawaiʻi Department of Agriculture under the provisions of Hawaiʻi Revised Statutes (HRS), Chapter 141, Department of Agriculture, and Chapter 150A, Plant and Non-Domestic Animal Quarantine. The release has been following review and approval by the Hawaiʻi Board of Agriculture in consultation with the Advisory Subcommittee on Entomology and Advisory Committee on Plants and Animals (Appendix 1, Part 6).

After completion of the EA, the Hawaiʻi Department of Agriculture is expected to apply to the Hawaiʻi Department of Land and Natural Resources, Division of Forestry and Wildlife, for a permit for release and monitoring of the insect on State forest land under HRS Chapter 171, Public Lands, Chapter 183, Forest Reserves, and Chapter 195, Natural Area Reserves System.

1.5 Public Involvement and Agency Coordination

Public outreach has continued throughout this process through a series of formal and informal meetings, as well as phone and email communications with parties who have inquired about the action. The U.S. Forest Service has maintained a website on the issue that describes the development of biocontrol for strawberry guava and features frequently asked questions and photo galleries: http://www.fs.fed.us/psw/programs/ipif/strawberryguava/.

A series of open house meetings was hosted by the U.S. Forest Service to provide opportunities to learn about and discuss the threat strawberry guava poses to native Hawaiian forests and the proposed use of biocontrol to manage the species, as well as to gather citizen input for this EA. The meetings were held from 5:30 to 7:30 PM at:

- Maui - April 27, at the Maui Arts and Cultural Center in Kahului;
- Kauaʻi - April 29, at Chiefess Kamakahelei Middle School in Lihue;
- Oʻahu - April 30, at McCoy Pavilion at Ala Moana Park, Honolulu;
- Hawaiʻi Island, Hilo - May 14, at the University of Hawaiʻi at Hilo, Room UCB 127; and
- Hawaiʻi Island, Kona - May 18, at NELHA Gateway Center, Kailua-Kona.

The meetings had an open house format and included opportunities for attendees to provide written comments for consideration during EA preparation. Issues raised in these comments are included in those summarized in Table 1, below. Scientists from the Institute of Pacific Islands Forestry, the Hawaiʻi Department of Agriculture, Hawaiʻi Invasive Species Council, and other agencies assisted in the meetings.

In addition, the U.S. Forest Service and its consultants engaged in a series of informal meetings with a variety of groups and individuals between March 1 and May 16, 2009.

List of Consulted Parties

A partial list of those from whom information and comments were solicited and/or presentations were made include the following:

Individuals and Organizations:

Amy Greenwell Ethnobotanical Garden
Big Island Invasive Species Council
James Cuda, University of Florida, Entomology & Nematology Department
Edith Kanakaʻole Foundation
Entomological Society of America

Hawaiʻi Watershed Partnerships
Hawaiian Entomological Society
Christopher J. Hodgson, The National Museum of Wales
Kanaka Council
Jose Henrique Pedrosa Macedo, Universidade Federal de Parana, Curitiba, Brazil
Maui Conservation Alliance
Na Oiwi Olino (OHA sponsored)
Jamie Reynolds, Plant It Hawaii
Rotary Club of Volcano
Rotary Club of Hilo
Bryan Sagon, Guava Consultant
Sierra Club, Hawaiʻi Chapter
Sierra Club Moku Loa Group Executive Committee
Clifford Smith, University of Hawaiʻi at Manoa, Botany Department (retired)
The Nature Conservancy
Three Mountain Alliance
Eric Vanderwerf, Pacific Rim Conservation
Marcelo Vitorino, Universidade Regional de Blumenau, Brazil
Weed Science Society of America
Frank Wessels, University of Florida, Entomology & Nematology Department
Charles Wikler, Universidade Estadual Centro-Oeste, Irati, Brazil

County Agencies and Officials:

Hawai‘i County Councilmembers Dominic Yagong, Bob Jacobson, Pete Hoffman, Brenda Ford, Guy Enriques and Dennis Onishi
Hawai‘i County Council IGRPW Committee

State Agencies and Officials:

Department of Agriculture, Advisory Subcommittee on Entomology, Advisory Committee on Plants and Animals
Department of Agriculture, Plant Pest Control Branch
Office of Hawaiian Affairs
Representative Clift Tsuji
Senator Lorraine Inouye
University of Hawai‘i at Hilo
University of Hawai‘i at Manoa, College of Tropical Agriculture and Human Resources

Federal Agencies and Officials:

Hawai‘i Volcanoes (HAVO) National Park
Haleakala National Park
Representative Maizie Hirono
Senator Daniel Akaka
U.S. Fish and Wildlife Service, Pacific Division of Ecological Services
U.S. Geological Survey, Pacific Island Ecosystems Research Center, Kilauea and Haleakala
U.S. Natural Resources Conservation Service, Dave Clausnitzer

Issues Identified to Date

Table 1 identifies the principal questions and concerns identified by parties in communications related to the withdrawn EA, in communications outside the EA process, and in public meetings. The table also includes a brief summary of the response of the Hawai‘i Department of Agriculture to each concern, referenced to locations in the Draft EA, where applicable, where the issue is discussed.

Table 1
Summary of Issues Raised During Consultation

Question or Concern	Response of Hawai‘i Department of Agriculture
T. ovatus (“the insect”) may jump to attack other plants, particularly Myrtaceae, or valuable crop plants such as coffee, common guava, mango, or papaya.	The insect is highly specific and has been rigorously tested on over 100 plants, including close relatives (App. 1). In its native range *T. ovatus* has never attacked agricultural crops
The insect may evolve such abilities.	The time scale of evolution is very long; at such scales, thousands of species of insects have opportunity to evolve such characteristics. Gall-forming insects are actually more constrained in potential for evolutionary shifts than most other insects, because of their close interaction with their host plants. (Sec. 3.1.2)
The insect will be a pest to humans (like a gnat) and will be make life “miserable”.	This insect spends almost all its life attached to a leaf without moving. Females cannot fly or even leave their galls; males are weak fliers that live only about 2 days and have never been known to swarm or bother humans in any way.
The insect may multiply out of control to extreme densities.	Like any other highly host-specific plant feeders, *T. ovatus* populations are limited by the abundance of their host plant. As a gall-former, this insect is further limited naturally by abundance and accessibility of the new leaf tissue on which it forms galls.
T. ovatus may prove to be an allergen.	Among hundreds of species of soft scale insects around the world, including many very abundant pest species, allergic reactions are not known to be an issue.
The insect’s natural predators or pathogens may come to Hawai‘i and harm native insects.	*T. ovatus* has 3 highly specialized enemies in its native range. One of these (a tiny parasitic wasp) is widespread around the world and may already occur in Hawai‘i. This wasp’s host relationships are poorly known (populations occurring in Hawai‘i may be unable to feed on *T. ovatus*), but it utilizes only soft scale insects, most of which are considered pests (Sec. 3.12)
Scale insects (like *T. ovatus*) commonly stimulate ant populations by providing them food (honeydew).	Not all scale insects produce honeydew. *T. ovatus* does not, and no association with ants has ever been observed for this insect in its native range.
We will lose fruit for food (jams, jellies, wine, sauces, lemonade), affecting our sustainability.	There will still be fruit, especially on isolated trees and shrubs, and individual trees and shrubs can be protected by horticultural oil sprays, including natural oils (Sec. 3.2.1).
It will reduce food for wild pigs, negatively impacting pig populations, pig hunting and the food this produces; alternatively: it may drive pigs into people’s gardens and farms to get food.	Strawberry guava fruit, though seasonally abundant, is a relatively minor component of the diet of pigs, which are very adaptable. Hunting quality could increase with better access conditions (Secs. 3.1.2 and 3.5). Reduction of wild fruit near homes may reduce pigs and the damage they sometimes cause to gardens and residential landscapes.

Table 1, continued	
Biocontrol will cause loss of wood for smoking, furniture, fuel source, mulch.	The insect will not kill trees, but only reduce vigor and growth. Given the scale of the densest infestations, tens of thousands of acres with tens of millions of trees, wood will continue to be superabundant (Sec. 3.5).
Galls will make the trees ugly, affecting property values and tourism.	The galls are only visible close-up, and will not reduce the attractiveness of groves. Trees in Brazil are attractive in spite of galls. ʻOhiʻa trees have leaf galls (from a native insect) yet remain attractive (Sec. 3.6).
There will be a cumulative scenic impact when added to problems with rose apple and wiliwili.	*T. ovatus* does not produce severe defoliation or other effects highly visible on the level of the problems with wiliwili and rose apple; the impacts would thus not tend to accumulate (Sec. 3.6).
Insect will ruin value of trees as windbreak or privacy screening.	The insects do not defoliate but instead produce leaf galls. Vigor of new growth may be reduced, for example after pruning, but this can be remedied by planting other, less environmentally harmful trees (Sec. 3.2.5).
Strawberry guava leaves can be used medicinally to treat diarrhea.	Traditional diarrhea medicine usually involves common guava leaves, not strawberry guava. In any case, leaves will continue to remain superabundant. The gall areas can simply be cut away or leaves without galls can be used (Sec. 3.5).
Wood can be used for sticks in hula and lomilomi, and as an ʻoʻo.	The wood will remain superabundant and these uses will not diminish. Native trees that were the original materials for these tools will be allowed to continue to survive, for potential use in the future (Sec. 3.4).
Strawberry guava provides habitat for native birds and bats.	Strawberry guava thickets are poor habitat for native species. Degradation of native forests by strawberry guava is a primary threat to native plants and animals (Sec. 3.1.3-5)
Infested strawberry guava will despoil the beauty of the forest.	Visual impacts to strawberry guava will be minor, but increased and healthier native plants will have a large scenic benefit in the forest (Sec. 3.6).
Worse invasive plants will replace strawberry guava.	Ecologists and land managers feel there are currently very few plants as invasive as strawberry guava (Sec. 1.3). Because the insect does not kill trees, but only reduces vigor and growth, existing stands of strawberry guava will not be rapidly displaced.
Doesn’t strawberry guava control erosion and help recharge the islands’ aquifers?	In fact, strawberry guava allows less recharge to the aquifer than does native forest. Biocontrol is unlikely to increase erosion because impacts on existing stands of strawberry guava will be moderate and gradual. If stands were to decline over time, the gradual nature of the process would allow for replacement with other soil holding species. Protecting vast areas of native forest from degradation by strawberry guava is the best insurance against erosion since healthy Hawaiian forests are highly resistant to erosion. (Sec. 3.3).

Table 1, continued	
Strawberry guava produces oxygen to combat vog.	All plants produce oxygen, and all other things equal, native plants are preferable.
It would be better to manually remove it, or use some combination of manual and herbicide control. Volunteers or prison labor could do this. Or we could create a whole industry out of this, with the value of the wood paying for the eradication.	1) A great part of the infestation is in very difficult terrain, far from roads, dangerous and ecologically sensitive; 2) The required labor is extremely substantial; for East Hawai‘i alone, it would cost hundreds of millions of dollars and require thousands of full-time workers (Sec. 2); 3) Strawberry guava wood is of limited value, and there is no use that could pay for more than a small fraction of removal costs in most areas (Sec. 3.2.4).
How about girdling trees? Tethering goats near seedlings?	Such methods could have limited value in small areas, but cannot play any large role in wide scale control across hundreds of thousands of acres (Sec. 2).
Strawberry guava would make a great biomass resource.	Current research indicates that despite its prevalence, strawberry guava is a poor candidate for biofuel (Sec. 3.2.4). Efficient harvesting (e.g, by bulldozer) would cause substantial ecological damage, and access is a severe challenge for the vast majority of affected areas.
Strawberry guava doesn’t really hurt the forest, and besides, there are other priority plants for biocontrol: Albizia, Tibouchina, Clidemia, maile pilau, autograph tree.	Conservation professionals in Hawai‘i agree that strawberry guava is the worst or nearly the worst invasive plant threatening Hawaiian forests (Sec. 1.4)
Strawberry guava only appears in disturbed areas.	Disturbance does promote strawberry guava, but it also has steadily invaded deeply into our most pristine forests and will continue to do so unless it is controlled.
Strawberry guava is not a source for fruit flies and control of this plant will have no effect on fruit fly density.	On the contrary, strawberry guava fruits are a significant host of fruit flies and many fruit growers and agricultural officials support keeping it under control (Sec. 3.2.3).
There will be increased risk of rockfall along roads and highways where strawberry guava helps hold the soil and rock, e.g., Hana Highway and the Pali Highway.	Strawberry guava trees will not be killed by *T. ovatus*. Gradual decline in the vigor of existing thickets will allow replacement by other species and will not cause catastrophic mass wasting (Sec. 3.3).
Biocontrol never works: heed the lesson of the mongoose and rat.	Over 50 biocontrol agents have been released in Hawai‘i against insect and weed targets since strict regulatory processes were established in the 1970s, and none has switched hosts to non-target species or become invasive themselves. Recent notable successes include biocontrols for banana poka and ivy gourd (Sec. 1.3).
Biocontrol is theoretically OK, but we just don’t need another insect in Hawai‘i.	Biocontrol introductions, which are rigorously studied and regulated, have a proven track record of safety and effectiveness. They are a truly necessary tool for our worst invasive species. *T. ovatus* in particular offers tremendous potential benefits to both native forests and our agricultural economy.

The Final EA will include copies of all written comments received in response to the Draft E.A. during the 30-day comment period as well as the responses of the Hawai‘i Department of Agriculture to each letter.

PART 2: ALTERNATIVES

This section will explain the two alternatives available: the action alternative, for DLNR to issue a permit for release and monitoring of the *T. ovatus* insect on State forest land; and no action (not issuing this permit).

Although these alternatives are limited to a decision on whether to permit release of *T. ovatus* in Hawaiʻi, other methods can be used for control of strawberry guava. Some are presently being used by public agencies and private organizations and individuals to control infestations in limited areas. These are described last in this section in the context of alternatives evaluated but dismissed from further consideration, as they did not meet the purpose of effectively reducing the damaging effects of infestations of strawberry guava in large areas of the Hawaiian Islands.

2.1 Proposed Action

Under this alternative, DLNR would issue a permit for release and monitoring of the insect on State forest land for the control of strawberry guava on various lands in the State Forest Reserve and in Natural Area Reserves throughout the State of Hawaiʻi, an action which has already received the necessary field release permits from the Hawaiʻi Department of Agriculture and USDA-APHIS (see Appendix 1). Conditions for environmental release of *T. ovatus* in Hawaiʻi have been established by the Hawaiʻi Department of Agriculture (Appendix 1, Part 6).

2.2 No Action Alternative

Under the no action alternative, DLNR would not issue a permit for release and monitoring of the insect on State forest land for the control of strawberry guava. The limited chemical, cultural, and mechanical control methods currently practiced by other agencies and individuals around the State would continue under the no action alternative, but they would likely be ineffective in controlling strawberry guava on a landscape level (see next section).

2.3 Alternatives Evaluated and Dismissed from Further Consideration

Areas for Release of Biocontrol Agent

Sites considered for release of the insect include State and federally managed forests and research sites on each of the main Hawaiian Islands where strawberry guava occurs. Although release at any of these sites has been permitted by the Hawaiʻi Department of Agriculture and USDA-APHIS (Appendix 1), release is proposed specifically in lands managed by the Hawaiʻi DLNR because large areas of these State lands are under immediate threat from invading strawberry guava (see Figures 1a, 1b). If releases were not conducted in DLNR-managed forests, but were conducted on land outside these areas, the biocontrol agent would likely spread into the State-managed forests over time by means of natural dispersal. Therefore, restricting release to areas outside of State-managed forests would probably delay though not eliminate the potential effects of biocontrol of strawberry guava in State forest lands, resulting in further degradation of native forests as described under the no action alternative.

Another alternative for deploying the biocontrol agent would be to restrict its release to one island or one forest area within an island. This option might be considered useful for limiting the risks of a particular biocontrol until such a time that they might be better understood and mitigated. However, benefits and risks of biocontrol are typically consistent across the State, and movement of organisms within the State is often difficult to control. Like most insect species that establish in Hawaii, populations of the proposed biocontrol agent are expected to extend over time to all areas where there is suitable habitat. Limiting an insect species to one remote site is not realistic based on past experience. In the case of strawberry guava, using biocontrol as an additional management tool is expected to produce benefits that extend statewide (Part 3 in this document). Also, given that the risks of using biocontrol have been evaluated at a statewide level and determined to be minimal by State and federal regulatory processes for biocontrol introductions, restricting release of the biocontrol agent to a single area does not appear to have any significant mitigating effect in the long term.

In the short term (over the first several years), releases would occur at specific sites to allow monitoring of the impacts of biocontrol on strawberry guava invasions. Results of monitoring will be used to design effective long term management of strawberry guava statewide, integrating biocontrol with mechanical and herbicidal control methods to maximize potential benefits (Sec. 1.1). Releasing only at a single remote site would likely impede monitoring and adaptive management, whereas conducting the initial release at an accessible and easily monitored site will allow better development of effective integrated management of strawberry guava and efficient application of this management statewide.

Existing Control Methods

Aside from biocontrol, there are various means to combat the spread of strawberry guava. Some can be very effective for limited areas, but none are effective on the landscape level. Furthermore, these methods are very expensive and can involve significant environmental damage as side-effects. Each potential method was evaluated.

- Herbicides can be effective for control in limited areas with low density infestations (Tunison and Stone 1992). According to Motooka et al (2003) strawberry guava is "sensitive to foliar, frill and cut-surface applications of triclopyr, dicamba, and 2,4-D, in descending order of efficacy….also sensitive to basal bark applications of 2,4-D, picloram and triclopyr." For limited areas, Hawaiʻi Volcanoes National Park commonly uses a 10% Garlon 3a or 50% triclopyr amine in water with a cut stump method. However, control of strawberry guava using herbicides through aerial or other widespread applications is prohibitively expensive and would also generally be environmentally unacceptable because of water quality and other concerns. Even local applications may have undesirable side effects, such as killing adjacent plants and chemical contamination of the soil or waterways. Cut-stump treatments can be effective, but they carry the risk of resprouts from slash in wet areas (Tunison 1991). Widespread herbicide applications are also controversial and unpopular. In areas of dense thickets, treating all trees per acre would exceed the allowable application rates for several commonly used herbicides.

- Mechanical control efforts are extremely labor intensive and prohibitively expensive as a general management tool. Strawberry guava plants resprout readily from cut stumps and slash piles. However, plants up to 5 centimeters in diameter can be removed on a limited scale using a weed wrench (Ward 2003). Digging up plants (grubbing) is a suitable control method for many agricultural and residential areas, but dense thickets are extremely time consuming to hand grub and difficult to penetrate even with large machinery. The generally undesirable ecological consequences of large-scale grubbing make it unacceptable in natural areas.
- Cultural techniques such as shading and fire are not likely to be effective to control strawberry guava. It is shade tolerant. No native or alien tree species are known which can grow up through it and shade it out. Controlled burning is not effective. Though aerial portions of the plant are killed by intense fires, the plants rapidly resprout from the basal portion. In ranchlands, there are generally insufficient fuel levels to generate sufficient heat to kill the trees. In natural areas fire is unacceptable as a management tool.

Herbicide and mechanical techniques are being applied in various areas of the Hawaiian Islands, particularly where complete eradication of strawberry guava in limited areas is desired, for example, by farmers on cultivated plots or in parks along trails that are meant to show native forests. The Hawaiʻi Division of Forestry and Wildlife conducts control activities of strawberry guava along trails using both mechanical and herbicide methods. The Hawaiʻi Department of Transportation, County Public Works agencies, and utility companies conduct control measures of strawberry guava along roads and utility right-of-ways. The National Park Service and The Nature Conservancy Hawaiʻi have programs to control strawberry guava in natural areas. At Hawaiʻi Volcanoes National Park (HVNP), strawberry guava has been targeted for control since 1985 in Special Ecological Areas, selected for intactness of native vegetation, high species diversity, rare flora and manageability (Tunison and Stone 1992). Dramatic reductions in density of strawberry guava and other weeds have been achieved within these limited areas, and the labor to maintain low weed density declines after the initial large investment. However, as densities of strawberry guava increase outside the boundaries of Special Ecological Areas, their vulnerability to invasion and the cost of maintaining them can be expected to increase (Tunison and Stone 1992). A commercial koa operation that proposed to use land in both the State Land Use Agricultural and Conservation districts found that community and environmental groups considered large-scale disruption caused by herbicides and bulldozing unacceptable in the Conservation district (Wade Lee personal communication to Ron Terry, 2007).

Successful herbicide or mechanical treatment can be conducted in areas that are small, adjacent to existing roads, and not highly sensitive for reasons of erosion, water resources, or neighbors. In such areas, the treatments would likely be more successful with the synergy provided by biocontrol. However, these treatments are not effective over large tracts, within areas remote from roads, or in certain environmentally sensitive contexts. For this reason, they could not meet the purpose of effectively reducing the damaging effects of infestations of strawberry guava over large portions of the native forests of the Hawaiian Islands and do not provide a viable alternative to the proposed action.

Cost is another important consideration. The proposed action is expected to substantially reduce the vigor of strawberry guava over the thousands of acres that are currently invaded, and to reduce the spread of strawberry guava into as much as half the area of the six main islands. Dr. Jonathan Price of the University of Hawaiʻi at Hilo, Department of Geography, led a team that conducted an evaluation of the cost of removing strawberry guava through mechanical and herbicide methods under a variety of infestation and distance scenarios. His work is reproduced in Appendix 2 and summarized here.

Labor was estimated a rate of $200 per worker day, typical of entry-level conservation work. Based on consultation with resource managers experienced in control of forest weeds (including strawberry guava), Price estimated that dense infestations would take about 50 worker-days per acre, and incipient invasions consisting of scattered trees would take about one worker-day per acre.

Control methods include cutting all strawberry guava stems and applying herbicide to prevent resprouting. Control of the numerous seedlings and any subsequent growth would occur during a secondary sweep of each control area. Because only a few areas are easily accessible by road, extra costs associated with work in more remote areas were considered. Away from roads, workers would need to carry equipment through dense vegetation and over rugged terrain. Areas more than about a third of a mile from a road require extra time for work crews to access and therefore a higher cost per acre. Areas more than 1.5 miles away are too remote to work on a day-by-day basis, and would involve work crews camping, usually with helicopter transport for equipment and camping gear. Costs were broken down according to the severity of the infestation and the distance from roads, and maps of these attributes were combined in a Geographic Information System (GIS) in order to determine how much area has a given combination of characteristics (see Maps 1 through 4 in Appendix 2). Table 2 presents the results of the cost estimates, and Figure 5 illustrates cost zones for East Hawaiʻi conservation areas.

Table 2
Cost Estimates for Control of Strawberry Guava, East Hawaiʻi Conservation Areas

Incipient Invasions Near roads: 31,600 acres × $250/acre = $7,900,000 Moderate Distance: 86,800 acres × $284/acre = $24,651,000 Remote: 61,300 acres × $506/acre = $31,018,000
Dense Infestations Near roads: 9,200 acres × $10,500/acre = $96,000,000 Moderate Distance: 11,900 acres × $12,200/acre = $145,180,000 Remote: 2,700 acres × $23,315/acre = $62,950,000
Total Cost: $367,700,000

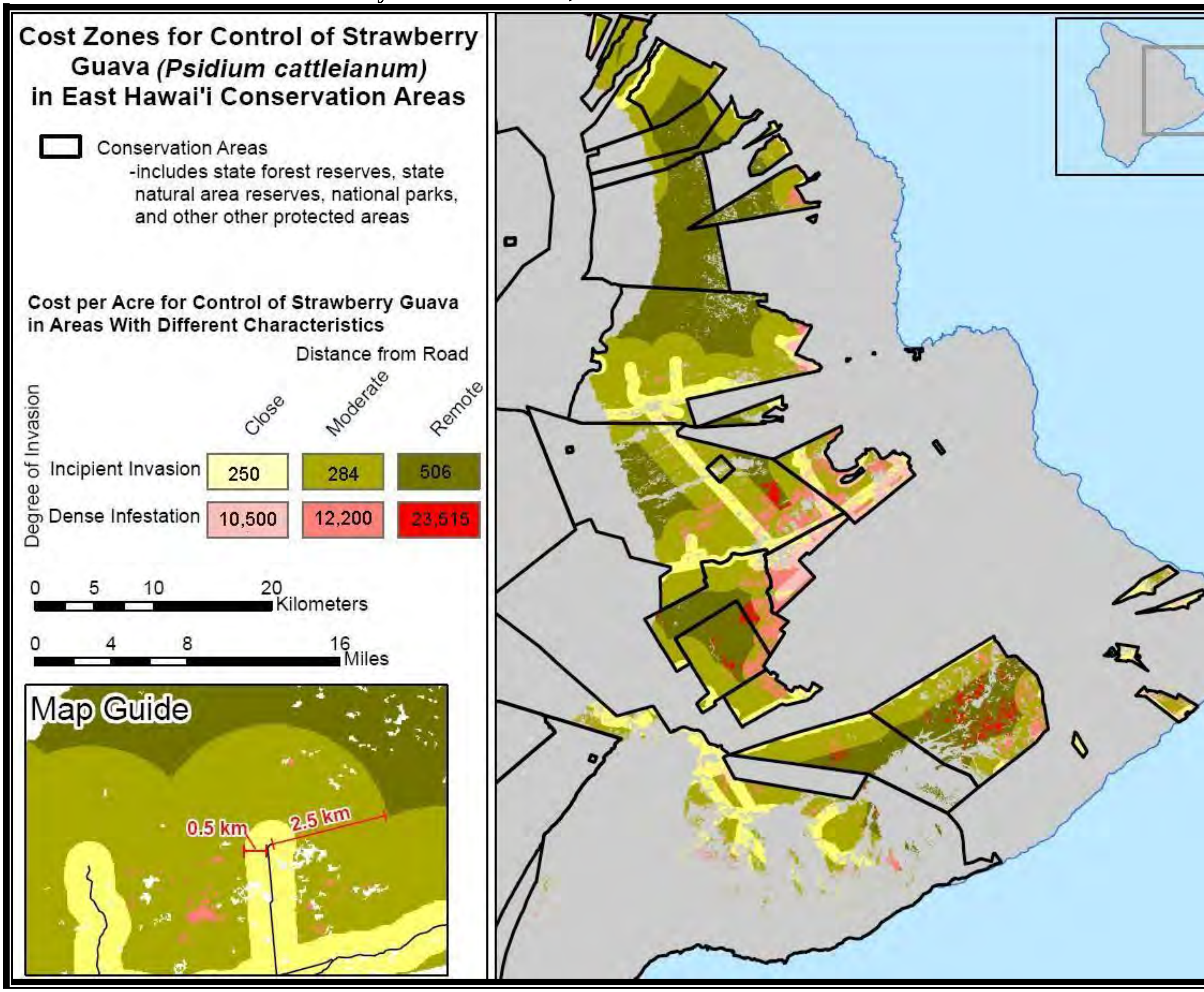
Given the density of the infestation and the difficulty of the terrain in which removal would take place, the total of over a third of a billion dollars appears accurate but far beyond what most would consider the reasonable value of the endeavor. As most of the expense is labor, the effort would also require over 1.5 million labor days; i.e., a full-time job for a year for 6,000 individuals.

In light of the extremely high estimated costs for removal, other approaches or limited scopes were also examined. While removal of strawberry guava for biomass fuel or material uses has been proposed as a way to defray the cost of control, this would only be feasible in areas close to roads (a small fraction of the total area). Removal of large amounts of biomass from remote areas would only be possible by helicopter, which would add far more cost than any potential value gained. Section 3.2 of this EA has a discussion of the potential for strawberry guava to be used as a biomass fuel.

Building additional roads for access was not considered feasible due to added costs and the legal limitations of road construction in areas zoned for conservation or designated as endangered species habitat.

Because strawberry guava produces numerous seeds, a secondary sweep (after perhaps 3-4 years) of each treated area would be necessary to control seedlings. This would likely incur a cost similar to that for incipient invasion across the entire region (estimated at an additional total of about $70,000,000 for the secondary sweep). Continued dispersal from non-controlled areas may require additional sweeps near the boundaries of controlled areas, adding an unknown cost.

Figure 5
Cost Zones for Strawberry Guava Control, East Hawai‘i Conservation Areas



PART 3: ENVIRONMENTAL SETTING, IMPACTS AND MITIGATION MEASURES

Introduction

Unlike many other projects, which may directly affect only a very limited area that can be measured and described systematically, the proposed project treats vast areas of the Hawaiian Islands. The proposed biocontrol of strawberry guava would eventually affect all areas where strawberry guava occurs in the Hawaiian Islands, particularly locations where it occurs in the wild with some abundance. Figures 1a-b above show the general distribution of strawberry guava around the State of Hawaiʻi. Note that it does not occur on Kahoʻolawe or Niʻihau, but in some locations on all other islands. Although strawberry guava is seen wild in areas with annual rainfall as low as 40 inches and can tolerate the low temperatures found up to roughly 5,000 feet in elevation, it is generally concentrated between sea level and 4,000 feet on the windward sides of islands or at cooler and moister elevations in some leeward areas. Although it is found at sea level in coastal areas, it is not highly salt tolerant and is not part of the shoreline flora.

It is found scattered in nearly pristine native forests, disturbed native forests, and non-native forests, and also invades pasture land and farms. Strawberry guava is not particular as to substrate and it is found in soils of all types, from deep ash to weathered lava to young lava flows. As a result, it is found in many hydrological contexts as well, from areas without streams to highly dissected landscapes, on all types of slopes. Although not classified as a wetland plant, it is reasonably tolerant of short periods of standing water as well.

Many casual observers believe that strawberry guava is confined to hedgerows along roads and does not invade the native forest without some pre-existing human disturbance. In reality, it is a very effective invader and is found deep in roadless areas, as shown in Figures 1b and 1c. Like an iceberg, the visible roadside strawberry guava hedges are only the tip of a very extensive infestation that extends deep into the mauka forests. The mauka-makai Hawaiian land management principles behind the concept of ahupuaʻa are applicable here: the uplands, lowlands, and coastal waters are all connected through the hydrological cycle. The role of strawberry guava in this interaction is discussed below in Section 3.3.

The remainder of this chapter is a resource-by-resource discussion of the consequences of the two alternatives described in Section 2 above that are available: the action alternative, for DLNR to issue a permit for release and monitoring of the insect on State forest land; and no action (not issuing this permit). Projects may generate three different types of environmental impacts: direct, secondary, and cumulative. Direct impacts are those that obviously result directly from the action itself. Secondary impacts (sometimes called indirect impacts) occur later in time or farther removed in distance or through less direct connections, but are still reasonably foreseeable. Cumulative impacts are defined as the impact on the environment that results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions, regardless of what agencies or person undertakes such other actions. In this EA, where potential exists for secondary or cumulative impacts, these are discussed along with direct impacts in the resource-based discussion.

3.1 Biological Resources

3.1.1 Direct Impacts on Strawberry Guava

Action Alternative

T. ovatus is expected to affect directly only the target weed strawberry guava in Hawaiʻi. *T. ovatus* would cause leaf galls on strawberry guava that reduce the vigor of the plant. The effects may differ from plant to plant and even branch to branch, and will generally be subtle and gradual. This would lead to a 25 to 40 percent reduction in vegetative growth rate and 60 to 90 percent reduction in fruit and seed production, similar to levels seen in its native Brazil (J.H. Pedrosa Macedo and M. Vitorino personal communication to Tracy Johnson, April 2009; J.H. Pedrosa Macedo 2005, unpublished report). High levels of infestation have been observed to cause leaf drop to the point of complete defoliation of strawberry guava in Brazil (Vitorino et al. 2000). This level of damage is relatively rare, however, and may involve combined stresses from other factors such as drought. Both dispersal by seeds and vegetative propagation by clonal sprouts should decline over a period of years where *T. ovatus* becomes established.

Impacts of *T. ovatus* on strawberry guava are expected to occur gradually over a period of decades, providing long-term suppression, allowing natural substitution of strawberry guava by other plant species, and preventing spread of strawberry guava into areas at risk from invasion. Acceleration of this process may be possible over selected areas by combining mechanical or herbicidal control with suppression by *T. ovatus*. Effective biological control of strawberry guava is expected to complement and benefit other weed management programs, for example, increasing the efficacy of mechanical removal of strawberry guava by slowing the weed's ability to resprout from surviving stems. One key to the expected success of mechanical/chemical control is that strawberry guava exhibits little seed dormancy. The absence of a seed bank means that reduction in fruit production will strongly reduce the plant's ability to recolonize following control (Uowolo and Denslow 2008). To the extent that *T. ovatus* enhances conventional control of strawberry guava, it may promote additional use of chemical or mechanical methods against this weed over larger areas of land. In these cases it may be appropriate to plan for active restoration of controlled areas, such as by introducing native species. The positive and negative impacts of greater use of chemical or mechanical methods against strawberry guava would depend on the care taken to avoid damage and promote restoration of native ecosystems.

There is some uncertainty associated with the effectiveness of *T. ovatus* for control of strawberry guava. Although observations in Brazil and laboratory tests indicate that this agent can significantly impact individual strawberry guava plants, it may not reduce strawberry guava population growth to desired levels in all areas of Hawaiʻi. Worldwide, biological weed control programs have had an overall success rate of 33 percent; success rates have been considerably higher for programs in some individual countries (Culliney 2005). Actual effectiveness of *T. ovatus* for controlling strawberry guava will not be known until after release occurs and post-release monitoring has been conducted.

Mitigation Measures

The monitoring program will provide information on the rate of dispersal of *T. ovatus* and success of control, focusing on the effects on strawberry guava population growth. The U.S. Forest Service also plans to study the interaction of mechanical control (cutting and stump-herbicide) and biocontrol. The monitoring will provide guidance on future actions, including consideration of methods for dispersing *T. ovatus*, alternate biocontrol agents, and combination methods of treatment for certain areas.

No-Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and efforts to reduce the abundance and range of this species likely would be restricted to chemical and manual methods in limited areas.

3.1.2 Direct and Secondary Impacts on Individual Nontarget Plants and Animals

Action Alternative: Direct Impacts

As discussed in Section 1.3, modern biocontrol requires rigorous testing. Since 1975, over 50 biocontrol species (including natural enemies for clidemia, banana poka, and ivy gourd) have been introduced to Hawaiʻi without any adverse effects. A biocontrol wasp agent for the wiliwili gall wasp, which has devastated this native tree important for both dry forest ecology and cultural uses, was released in November 2008 and appears to be providing effective suppression of the invader on surviving wiliwili. These examples illustrate how highly host-specific natural biocontrols have become critical tools in efforts to preserve Hawaiian ecosystems.

All laboratory tests and field observations indicate that *T. ovatus* is highly specialized to utilize only strawberry guava and closely related species within the genus *Psidium*, and no other plant species in Hawaiʻi would be affected by release of *T. ovatus*. These data all suggest a tight evolutionary and ecological link between *T. ovatus* and strawberry guava. Appendix 1 contains extensive information related to the testing of the host-specificity of this biocontrol agent that was conducted in order to obtain the USDA APHIS Plant Protection and Quarantine permits, issued on April 4, 2008.

Historically, host shifts by introduced weed biological control agents to unrelated plants are extremely rare (Pemberton 2000). However, if other plant species were to be attacked by *T. ovatus*, the resulting effects could be environmental impacts that may not be easily reversed, and thus the slight possibility that it could move from the target plant (strawberry guava) to attack nontarget plants must be considered. Species that are closely related to the target species are the most likely to be attacked. This well-established pattern forms the scientific basis of host specificity testing of proposed biological control agents (Louda et al. 2003). The material below provides an explanation of why it is extremely unlikely that *T. ovatus* would attack nontarget plants.

Strawberry guava and all members of the genus *Psidium* are part of the family Myrtaceae (subfamily Myrtoideae), which has 4,000 species worldwide with an evolutionary history extending across 50 million years (Sytsma et al 2004). The genus *Psidium* includes 50-100 neotropical species (McVaugh 1968). Hawai‘i has two well known introduced guavas, strawberry guava (*P. cattleianum*) and common guava (*P. guajava*). Within their genus, these two species appear to be distant relatives. There are no members of the genus *Psidium* that are native to Hawai‘i.

The family Myrtaceae is represented in Hawai‘i by 49 species in 9 genera. These include seven naturalized, one indigenous, and two endemic species in the subfamily Myrtoideae and 35 naturalized species and five endemic species in the subfamily Leptospermoideae (Wagner et al., 1990). The native species in the same subfamily as strawberry guava (Myrtoideae) are the endangered endemic *Eugenia koolauensis* Degener, the indigenous *E. reinwardtiana* (Blume) DC, and the endemic *Syzygium sandwicensis* (A. Gray) Nied. The dominant tree of native Hawaiian forests, *Metrosideros polymorpha* Gaud., and numerous introduced timber species, including *Eucalyptus* spp., are in the subfamily Leptospermoideae, and are thus more distantly related to strawberry guava.

The Myrtaceae are within the order Myrtales, which also includes the families Sonneratiaceae, Lythraceae, Rhynchocalycaceae, Alzateaceae, Penaeaceae, Crypteroniaceae, Thymelaeaceae, Trapaceae, Punicaceae, Onagraceae, Oliniaceae, Melastomataceae, and Combretaceae (Cronquist 1981). Of this group, only the Lythraceae and Thymelaeaceae include native Hawaiian species: *Lythrum maritimum* Kunth (Lythraceae) is an indigenous shrub, and there are up to 12 endemic species of *Wikstroemia* (Thymelaeaceae) (Wagner et al., 1990). Other families in the Myrtales with representatives naturalized in Hawai‘i are the Combretaceae (3 species in 2 genera), Onagraceae (10 species in 4 genera), and Melastomataceae (15 species in 12 genera, including a number of noxious invasive plants).

The tests conducted by the U.S. Forest Service took the above phylogenetic relationships into consideration, testing a broad range of related plants. Laboratory tests of *T. ovatus* host specificity in Brazil demonstrated that it could not develop on common guava, *Campomanesia xanthocarpa*, *Eucalyptus dunii*, *Eugenia uniflora*, or *Metrosideros polymorpha* (Vitorino et al. 2000). Quarantine tests of a broad spectrum of Hawaiian plant species (Appendix 1), including all ecologically prominent Myrtaceae and some uncommon native members of this family, indicate that no species in Hawai‘i other than strawberry guava is a suitable host for this insect. Host specificity tests conducted in Florida also support these results (Wessels et al. 2007; Appendix 1). Evidence that *T. ovatus* cannot develop even on *P. guajava* also includes over 15 years of observations of *T. ovatus* populations developing on strawberry guava in close proximity to *P. guajava* at field sites in Brazil (see Figure 2b). Within Brazilian literature on pests of common guava, *P. guajava*, there is no mention of *T. ovatus* or any gall-forming homopterans (scale insects, aphids and relatives).

There are very few records pertaining to *T. ovatus* and its biology in the literature. In his description of *T. ovatus,* Hempel (1900) noted that it formed galls on leaves of a plant in the Myrtaceae, and was not common. Ferris (1957) illustrated *T. ovatus* from specimens collected from *Psidium*. References to this insect in catalogs of coccoid scales in Brazil also recorded its host as Myrtaceae (Costa Lima 1927; Lepage 1938). With one exception that appears to be an error, existing literature are consistent with an extremely narrow host range for *T. ovatus*, restricted to *P. cattleianum* and sibling species that are not present in Hawaiʻi. One catalog recorded *T. ovatus* on *Daphnopsis racemosa* Griseb. (in the family Thymelaeaceae) (Hoy 1963); however, this reference is not well supported in other literature. In fact in a previous report Hoy (1962) makes the contradictory statement: "The Myrtaceae are the exclusive hosts for the genera *Apiococcus, Apiomorpha, Ascelis, Carpochloroides, Macracanthopyga* and *Tectococcus*." The record in Hoy (1963) appears to refer to a catalog by Costa Lima (1936) in which *T. ovatus* was recorded from "aracazeiro" and "embira." The former is a well-known common name for *P. cattleianum* in southeastern Brazil. "Embira" is more ambiguous. It may refer to *Daphnopsis racemosa* or species of *Anona* or *Rollinia* (in the family Annonaceae). The latter possibility suggests that Costa Lima's reference may be due to confusion between *T. ovatus* and its relative *Pseudotectococcus anonae*. Recent laboratory tests of *T. ovatus* specificity included species of Thymelaeaceae and Annonaceae; results indicated that these are not suitable host plants (Appendix 1).

T. ovatus has few close relatives, which suggests very low likelihood of evolution to use new host plants. There is only the single species, *T. ovatus*, in the genus *Tectococcus* (Hempel, 1900; Hoy, 1963). Hempel (1935) considered its closest relative to be *Pseudotectococcus anonae*, which he described from galls on leaves of a cultivated species of *Anona* (Annonaceae, the custard-apple family) in Vicosa, Minas Gerais, Brazil. Another genus containing only one species described by Hempel (1937), *Neotectococcus lenticularis*, was considered by Ferris (1957) to be possibly in the same genus as *Tectococcus*. This species also formed galls on the leaves of its host plant, which was identified only as a "wild shrub" in Itatinga, Brazil (Hempel, 1937). Although these related insect species use host plants in at least two entirely different families, their genetic relationships have never been studied, which prevents assessment of the genetic distance between them and the possible direction of future evolution.

The extremely close interaction of *T. ovatus* and its host *P. cattleianum*, typical of other gall-forming insects, constrains the insect from feeding on other plant species. A shift to a new host plant would require evolution of new traits, a process that might occur over a long interval of time. The timescale expected for *T. ovatus* to evolve the ability to use a new host plant is difficult to evaluate based on ecological genetics of closely related insect species because its relatives are so few and poorly known. Experience with agents for biocontrol of weeds over the last 100 years indicates that use of nontarget species has been almost entirely predictable (Pemberton 2000). Evolution of ability to use host plants in new, unpredictable ways has never been documented in over 1,100 cases of weed biocontrol worldwide over the last century. Evolutionary science suggests that, given sufficient time, such as thousands of years or more, novel traits are likely to appear naturally among insects introduced to Hawaiʻi (Gillespie and Roderick 2002), biocontrol agents included. Environmental consequences of such evolution would be largely unpredictable and may not be easily reversed. Past patterns of insect evolution in Hawaiʻi suggest that, while evolution may result in new species and new associations over a large time scale, it is not a major threat to maintenance of a highly diverse and unique biota. It should be recognized that the time scale of evolution is very long; at such scales, thousands of other species of insects also have an opportunity to evolve new characteristics.

T. ovatus does not feed on or otherwise directly affect any invertebrate or any other animal species.

Action Alternative: Secondary Impacts

Secondary impacts on nontarget species have been documented in a few cases of weed biocontrol, and experience has shown that such effects can be difficult to predict (Coombs et al. 2004). In general however, undesirable secondary impacts have been uncommon, especially for highly host-specific biocontrol agents.

Herbivory of strawberry guava plants is currently negligible; therefore *T. ovatus* is not likely to compete directly with any herbivores already in Hawaiʻi. Its major effect on other species is likely to be through reduced fruit production. A variety of non-native species utilize strawberry guava fruit seasonally, and some of these species may be affected to varying degrees. Pigs (*Sus scrofa*), which feed heavily on strawberry guava fruit when it is in season (Diong 1982), may be forced to find other food sources in the short term and may experience reduced population growth in the long term in areas where their dependence on strawberry guava fruit is currently high. The feral pigs that today inhabit much of Hawaiʻi's forests are not the same physically and not used in the same cultural manner as the smaller, domesticated pigs brought to the islands by voyaging Polynesians. Pigs are not native to Hawaiian forests and pig hunting was not a practice in ancient Hawaiʻi (Burrows et al 2007). As feral pigs are not natives and are generally recognized to be deleterious to native ecosystems, adverse effects to pig populations may be regarded as environmentally beneficial; however, the issue also deserves consideration in the context of cultural impacts (see Section 3.4) and particularly, socioeconomic impacts (see Section 3.5). Rats, mice, and non-native birds all probably benefit somewhat from current levels of fruit production, although their use of strawberry guava is not well quantified. Any negative impacts on these species would generally be expected to benefit native ecosystems that are negatively affected by these non-natives in a variety of ways (for example, disrupting native plant and animal life cycles, and spreading invasive alien plants). Alien fruit flies, including major agricultural pests such as the oriental fruit fly, can be expected to experience local population declines as a result of biocontrol of strawberry guava (see Section 3.2 below for discussion of fruit flies).

T. ovatus is not expected to be heavily attacked by natural enemies in Hawai‘i because it lies protected inside a gall for most of its life, and there are few related insects in Hawai‘i that appear likely to share its natural enemies. One parasitoid known to attack *T. ovatus* in Brazil, *Metaphycus flavus* (Vitorino et al. 2000), also is recorded from Hawai‘i (Nishida 2002), but it is unknown whether the Hawai‘i biotype of this parasitoid is able to utilize *T. ovatus*. Other specialized enemies of *T. ovatus* are only known in Brazil and are unlikely to travel to Hawai‘i. If these or other natural enemies are able to attack *T. ovatus,* it is possible that populations might build up on *T. ovatus* to a point that they could have significant spill-over effects on other insect hosts or prey species. Impacts mediated through a natural enemy shared with *T. ovatus* most likely would be a risk only to soft-bodied scale insects in the superfamily Coccoidea, which includes native and non-native species (Zimmerman 1948).

Mitigation Measures

Although adverse direct and secondary effects on nontarget plant and animal species and vegetation are theoretically possible, the high specificity of *T. ovatus* for strawberry guava and the fact that is only reduces vigor but does not kill its host plant indicate that adverse direct and secondary effects will not occur. Impacts of *T. ovatus* on nontarget species will be monitored at release sites in native forest plots where density of selected native species will be measured over several years. Releases in experimental plantings of strawberry guava bordered by *P. guajava* will provide demonstrations of specificity of *T. ovatus*. Semiannual reports provided to the Hawai‘i Department of Agriculture Plant Quarantine Branch will record all findings regarding nontarget species. Ongoing landscape-level studies of Hawaiian forests such as those called for in *Hawaii's Comprehensive Wildlife Conservation Strategy* (Mitchell et al 2005) will also provide data on the effects of this biocontrol, which, as discussed below, are expected to be primarily highly beneficial.

No Action Alternative

Under the o ction alternative, the biocontrol agent would not be released on State land, and effects from *T. ovatus* on nontarget species could of course be avoided.

3.1.3 Secondary Impacts on the Forest Ecosystem

Action Alternative

Although few if any adverse direct or secondary impacts to individual nontarget native species are expected, beneficial impacts to the general forest ecosystem are expected to be substantial. Most importantly, biocontrol of strawberry guava will favor native nontarget species by protecting large areas of native forest from being invaded and dominated by strawberry guava.

Because of the lack of natural biocontrol agents in Hawai‘i, the ecology of strawberry guava in Hawai‘i is completely different from that of its native range in Brazil. Furthermore, in a recent manual on koa silviculture, the authors note that invasive species can actually create forest structures new to Hawaiian ecosystems (Baker et al 2009). In the absence of natural predators or control agents, strawberry guava invades native forests and forms thickets that eventually exclude virtually all other vegetation (see Figures 1c and 3, above).

Dominant species such as ‘ohi‘a, koa and hapu‘u become restricted to scattered aging trees with no regeneration (Baker et al 2009). Subdominant plants become rare, and rare plants disappear entirely. In the words of biologist Jonathan Price:

> “A photo taken near Glenwood on the Big Island in 1917 shows an impressive native forest of enormous ‘ohi‘a trees draped in ‘ie‘ie vines. Here lived a plant found nowhere else: the giant haha (*Cyanea giffardii*). Today Glenwood is the site of one of the worst infestations of strawberry guava in Hawaii, and the giant haha is extinct” (Honolulu Star-Bulletin, June 14, 2008.).

This unfortunate story of forest ecosystem degradation has been repeated over and over around the Hawaiian Islands in areas invaded by strawberry guava, as discussed in Section 1.3.

Whether strawberry guava under suppression by biocontrol is replaced over time by native or alien plant species will depend upon a number of factors, including the climate and geology of the particularly location, its history of disturbance, the vegetation context, and human intervention. In lowland areas already disturbed and/or heavily infested by invasive aliens, replacement of strawberry guava by primarily alien species is more likely than replacement by natives, in the absence of active human intervention. In native forest, the chances of natives replacing strawberry guava, which is often the pioneer and primary serious invader, are much greater.

Because the impact of *T. ovatus* on strawberry guava populations is expected to be gradual, reducing recruitment and plant vigor over a period of many years, chances for replacement with native species is expected to be higher than if strawberry guava were removed suddenly, for example by mechanical and/or herbicidal treatment. This advantage to gradual control has been demonstrated experimentally with faya tree (*Morella faya*) in Hawaiian rainforests (Loh and Daehler 2007). In this case, gradually killing the invasive trees by full or partial girdling led to higher recruitment of native species and lower recruitment of weedy species compared with complete removal of the invasive trees. In some areas invaded by strawberry guava, particularly at higher elevations, there are relatively few other alien weeds present, so decline of growth and spread of strawberry guava is likely to benefit native species primarily. Thus, patches that would have been colonized and dominated by strawberry guava will probably be filled by native species. In some areas, strawberry guava may tend to be replaced by other invasive species over time. Himalayan raspberry (*Rubus ellipticus*), faya tree, and kahili ginger (*Hedychium gardnerianum*) are examples of weeds that, like strawberry guava, can invade intact forests and form dense patches excluding native plants.

Other invasive species may benefit if sunlight increases within patches of strawberry guava affected by biocontrol. For example, palm grass (*Setaria palmifolia*) and other invasive grasses (*Andropogon virginicus, Paspalum conjugatum*) that flourish in large forest gaps with high light levels may increase within stands of strawberry guava that may be partially defoliated by *T. ovatus*. In general, however, a reduction in the vigor and fruiting of strawberry guava, currently a major weed in Hawaiʻi, will have a significant benefit in the preservation and restoration of the native elements in native forests.

Mitigation Measures

The monitoring program will include evaluation of vegetation change and effects to threatened and endangered species.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and efforts to reduce the abundance and range of this species would not have this potentially effective tool. Existing chemical and mechanical control methods, because of their expense, are not likely to be used at such a scale to cause extensive damage to nontarget organisms. However, because they are difficult to administer with perfect selectivity, chemical and mechanical techniques will kill some nontarget native plants in areas where they are used. Strawberry guava's ability to regenerate after these control efforts means that chemical and mechanical control are only temporarily effective and must be repeated, with possible long term cumulative impacts on nontarget species. These environmental consequences may occur even with the implementation of the biological control alternative, depending on the efficacy of *T. ovatus* for reducing strawberry guava populations in Hawaiʻi.

3.1.4 Secondary Impacts on Endangered Plant Species

Action Alternative

There are 317 species of plants and animals in the Hawaiian Islands that are federally listed as endangered or threatened. Plant species occurring in mesic and wet forests are most affected by strawberry guava and are most likely to benefit from control of this weed (Table 3).

One endangered plant in the family Myrtaceae occurs in Hawaiʻi, *Eugenia koolauensis* (nioi). USDA APHIS has determined that based on the host specificity of *T. ovatus*, there will be no effect on *Eugenia koolauensis.* Several *Eugenia* species, *Eugenia reinwardtiana* (Blume) DC, *E. uniflora* L., *E. axillaris* (Sw.) Willd., *E. foetida* Pers., *E. confusa* DC, and *E. rhombea* Krug & Urban were tested in host specificity tests in Hawaiʻi and Florida, but no galls formed on these plants or on any other plant tested besides some closely-related *Psidium* species.

Table 3. Endangered and Threatened Plants Threatened by Strawberry Guava

Species	Common name	Island(s) with critical habitat affected by *P. cattleianum*	Status
Abutilon sandwicense	-	Oahu	E
Adenophorus periens	Pendant kihi fern	Kauai, Molokai	E
Alectryon macrococcus	Mahoe	Kauai, Maui, Molokai, Oahu	E
Alsinidendron obovatum	-	Oahu	E
Bonamia menziesii	-	Oahu	E
Brighamia insignis	Olulu	Kauai	E
Cenchrus agrimonioides	Kamanomano	Oahu	E
Chamaesyce halemanui	-	Kauai	E
Chamaesyce herbstii	‘Akoko	Oahu	E
Chamaesyce rockii	‘Akoko	Oahu	E
Colubrina oppositifolia	Kauila	Oahu	E
Ctenitis squamigera	Pauoa	Kauai, Lanai, Maui, Oahu	E
Cyanea (=Rollandia) crispa	-	Oahu	E
Cyanea grimesiana ssp. *grimesiana*	Haha	Oahu	E
Cyanea grimesiana ssp. *obatae*	Haha	Oahu	E
Cyanea humboldtiana	Haha	Oahu	E
Cyanea koolauensis	Haha	Oahu	E
Cyanea longiflora	Haha	Oahu	E
Cyanea pinnatifida	Haha	Oahu	E
Cyanea remyi	Haha	Kauai	E
Cyanea superba	Haha	Oahu	E
Cyanea truncata	Haha	Oahu	E
Cyanea undulata	Haha	Kauai	E
Cyrtandra dentata	Ha‘iwale	Oahu	E
Cyrtandra limahuliensis	Ha‘iwale	Kauai	T
Cyrtandra munroi	Ha‘iwale	Lanai, Maui	E
Cyrtandra viridiflora	Ha‘iwale	Oahu	E
Delissea subcordata	Oha	Oahu	E
Diellia erecta	Asplenium-leaved diellia	Molokai, Oahu	E
Diellia falcata	-	Oahu	E
Diellia unisora	-	Oahu	E
Dubautia latifolia	Na‘ena‘e	Kauai	E
Dubautia pauciflorula	Na‘ena‘e	Kauai	E
Eragrostis fosbergii	Fosberg's love grass	Oahu	E
Eugenia koolauensis	Nioi	Oahu	E
Euphorbia haeleeleana	‘Akoko	Oahu	E
Flueggea neowawraea	Mehamehame	Oahu	E
Gardenia mannii	Nanu	Oahu	E
Gouania meyenii	-	Kauai, Oahu	E
Gouania vitifolia	-	Oahu	E

Table 3, (Continued)
Threatened and Endangered Plant Species Threatened by Strawberry Guava.

Species	Common name	Island(s) with critical habitat affected by *P. cattleianum*	Status
Hedyotis degeneri	-	Oahu	E
Hedyotis mannii	Pilo	Lanai	E
Hedyotis schlechtendahliana var. *remyi*	Kopa	Lanai	E
Hesperomannia arborescens	-	Oahu	E
Hesperomannia arbuscula	-	Oahu	E
Hibiscus clayi	Clay's Hibiscus	Kauai	E
Isodendrion laurifolium	Aupaka	Oahu	E
Isodendrion longifolium	Aupaka	Oahu	T
Labordia cyrtandrae	Kamakahala	Oahu	E
Lipochaeta tenuifolia	Nehe	Oahu	E
Lycopodium (=Phlegmariurus) nutans	Wawae'iole	Kauai, Oahu	E
Melicope balloui	Alani	Maui	E
Melicope munroi	Alani	Lanai	E
Melicope ovalis	Alani	Maui	E
Melicope pallida	Alani	Oahu	E
Melicope saint-johnii	Alani	Oahu	E
Myrsine juddii	Kolea	Oahu	E
Myrsine linearifolia	Kolea	Kauai	T
Neraudia angulata	-	Oahu	E
Nototrichium humile	Kulu'i	Oahu	E
Phyllostegia hirsuta	-	Oahu	E
Phyllostegia kaalaensis	-	Oahu	E
Phyllostegia mollis	-	Oahu	E
Phyllostegia parviflora	-	Oahu	E
Pritchardia viscosa	Lo'ulu	Kauai	E
Pteralyxia kauaiensis	Kaulu	Kauai	E
Pteris lidgatei	-	Oahu	E
Schiedea hookeri	-	Oahu	E
Schiedea kaalae	-	Oahu	E
Schiedea membranacea	-	Kauai	E
Schiedea nuttallii	-	Oahu	E
Solanum sandwicense	'Aiakeakua, popolo	Kauai, Oahu	E
Stenogyne kanehoana	-	Oahu	E
Tetraplasandra gymnocarpa	'Ohe'ohe	Oahu	E
Urera kaalae	Opuhe	Oahu	E
Viola helenae	-	Kauai	E
Viola oahuensis	-	Oahu	E

Federally listed endangered (E) and threatened (T) plant species for which strawberry guava (*Psidium cattleianum*) has been noted by USFWS as a threat in critical habitat areas on the islands of Kauai, Oahu, Maui, Molokai and Lanai (USFWS 2003a-d).

Federal and State endangered species laws require government agencies to ensure that their actions are not likely to jeopardize the continued existence of federal or State listed threatened endangered species or result in the destruction or adverse modification of federal critical habitat. Although through its improvement of native forests the action has obvious and substantial benefits to all native plant species, particularly those that are rare, threatened or endangered, the U.S. Forest Service has carefully tested *T. ovatus* to ensure that it would not inadvertently attack non-target natives, as discussed above.

Mitigation Measures

As no adverse impacts to endangered plant species have been identified, no mitigation measures are necessary.

No-Action Alternative

Under the No-Action Alternative, no biocontrol of strawberry guava would be attempted on State land, and biocontrol of strawberry guava may not be available as a tool to protect and promote populations of threatened and endangered plant species.

3.1.5 Secondary Impacts on Endangered Animal Species

Action Alternative

A large number of threatened and endangered birds, invertebrates including insects and snails, and a single mammal, the Hawaiian hoary bat, depend upon the health of the native Hawaiian forest for their sustenance and survival (Table 4).Strawberry guava thickets provide little to no habitat for Hawaiʻi's remaining native birds. In areas of lower Puna where both strawberry guava and ʻohiʻa co-occur, the native ʻAmakihi (*Hemignathus virens*) and ʻApapane (*Himatione sanguinea*) were found to roost and forage almost exclusively in the native forest, while effectively ignoring the guava (Sugishita 2008). In addition, the federally funded Hawaiʻi Forest Bird Survey noted a consistent lack of native birds in strawberry guava forests (Scott et al 1986). Dominance by strawberry guava disrupts the close, million-year old relationships between native trees and native birds. Birds such as ʻAmakihi, ʻApapane, and ʻOmao (*Myadestes obscurus*) provide pollination and seed dispersal services for native plants. In turn, plants such as olapa, pilo, akala, kopiko, ʻieʻie, *Clermontia*, and kolea provide nectar and fruit resources for native birds (Perkins 1903; Patrick Hart personal communication to Ron Terry, 2009).

As discussed in Section 1.3, some biologists feel the threat posed by strawberry guava to the Hawaiian Petrel (*Pterodroma phaeopygia sandwichensis*) habitat in Lanaʻi is so extreme that it may become extinct there. This bird nests in uluhe on steep hillsides but strawberry guava is successfully colonizing and its roots are so dense that the petrels can no longer dig their burrows between them.

Table 4. Threatened/Endangered Animal Species in Strawberry Guava Threatened Forests

Species Name	Common Name	Status
Achatinella spp.	Snails, O'ahu Tree	E
Buteo solitarius	Hawk, Hawaiian	E
Chasiempis sandwichensis ibidus	Elepaio, O'ahu	E
Corvus hawaiiensis	Crow, Hawaiian	E
Drosophila heteroneura	Picture-wing fly	E
Erinna newcombi	Snail, Newcomb's	T
Hemignathus lucidus	Nukupu'u	E
Hemignathus munroi	Akiapola'au	E
Hemignathus procerus	Akialoa, Kaua'i	E
Lasiurus cinereus semotus	Bat, Hawaiian Hoary	E
Loxops coccineus coccineus	Akepa, Hawai'i	E
Loxops coccineus ochraceus	Akepa, Maui	E
Melamprosops phaeosoma	Po'ouli	E
Moho braccatus	'O'o, Kauai	E
Myadestes lanaiensis rutha	Thrush, Molokai	E
Myadestes myadestinus	Thrush, Large Kaua'i	E
Myadestes palmeri	Thrush, Small Kaua'i	E
Oreomystis mana	Creeper, Hawai'i	E
Palmeria dolei	Honeycreeper, Crested	E
Paroreomyza flammea	Creeper, Moloka'i	E
Paroreomyza maculata	Creeper, O'ahu	E
Pterodroma phaeopygia sandwichensis	Petrel, Hawaiian Dark-rumped	E
Pseudonestor xanthophrys	Parrotbill, Maui	E
Psittirostra psittacea	'O'u	E

Notes: E= Endangered; T= Threatened; List is partial. Source: USFWS 2009; http://www.endangeredspecie.com/states/hi.htm

Comments in response to the original Draft EA for the action included concerns by residents that because Hawaiian hoary bats feed on insects, reducing strawberry guava might also reduce insect populations that are associated with it, harming the bat. According to Hawaiian hoary bat expert Frank J. Bonaccorso, Ph.D. (personal communication to Tracy Johnson, 2009), the non-native fruit flies and mosquitoes associated with strawberry guava are not prey for Hawaiian hoary bats, which forage on insects that are at least one centimeter in size, such as beetles and termites. Furthermore, these bats would not use strawberry guava thickets as habitat, as they do not enter closed, cluttered forest where they cannot fly. It is likely that a reduction in strawberry guava thickets would benefit this bat, as it would other native species.

Native snails eat the fungus off 'ohi'a leaves. Any action that helps maintain a healthy 'ohi'a forest would likely be beneficial to native snails, including endangered species (Lisa Hadway personal communication to Frances Kinslow, 2009). Native snails are sometimes found on common guava and strawberry guava trees, but these plants are not essential to snail conservation (Robert Cowie personal communication to Tracy Johnson, 2009). According to biologist Daniel Chung, formerly with The Nature Conservancy and Bishop Museum, strawberry guava leaf litter makes very poor habitat for the native terrestrial snail species. The spread of guava is associated with a decline or disappearance of native terrestrial snails (Conservation Council 2009). Despite the overall benefit to snail habitat, it is not certain what would occur with individual snails or snail populations that currently are found on strawberry guava plants if the number of these plants is reduced.

In sum, no adverse impacts upon threatened or endangered animal species are foreseen from introducing a natural biocontrol agent that can reduce the vigor and spread of the invasive strawberry guava. The expected increase in forest health, including increased populations of rare, threatened or endangered species that have unique relationships with threatened or endangered birds and invertebrates, would provide a substantial benefit to all of these species, and may even prove critical for survival for some of them.

Mitigation Measures

As no adverse impacts to endangered animal species have been identified, no mitigation measures are necessary.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and biocontrol of strawberry guava would not be available as a tool to protect and restore native forests on State lands that provide habitat for threatened and endangered plant species.

3.1.6 Biological Impacts to Locations Outside of Hawaiʻi

Action Alternative

Although it under study in Florida as a potential biocontrol agent for a widespread strawberry guava invasion, there is concern in Florida about potential impacts of *T. ovatus* on native species of *Psidium*. More tests of specificity need to be conducted. Similar concerns might exist regarding species in the Caribbean. Considering the much closer distance and the far greater contact between Brazil (where *T. ovatus* is widespread) and Florida as compared to Hawaiʻi and Florida, the likelihood of Hawaiʻi acting as a source for an infestation of *T. ovatus* appears remote.

Mitigation Measures

Unauthorized or accidental transport of the insect to the U.S. mainland will be mitigated by the existing strict quarantine procedures for the export of fruit and plant products.

No Action Alternative
Under the no action alternative, risk of introducing *T. ovatus* from Hawaiʻi to Florida or areas outside of the U.S. could be avoided.

3.1.7 Cumulative Biological Impacts

Action Alternative

Past and present actions in Hawai'i to control strawberry guava include mechanical and chemical controls applied by a variety of State and federal agencies as well as private organizations and individuals. The Hawaiʻi Division of Forestry and Wildlife conducts control activities of strawberry guava along trails using mechanical and chemical methods. The Hawaiʻi Department of Transportation and utility companies conduct control measures of strawberry guava along roads and utility right-of-ways. The National Park Service and The Nature Conservancy Hawaiʻi have programs to control strawberry guava in natural areas. At Hawaiʻi Volcanoes National Park (HVNP), strawberry guava has been targeted for control since 1985 in Special Ecological Areas, selected for intactness of native vegetation, high species diversity, rare flora and manageability (Tunison and Stone 1992). Dramatic reductions in density of strawberry guava and other weeds have been achieved within these limited areas, and the labor to maintain low weed density declines after the initial large investment. However, as densities of strawberry guava increase outside the boundaries of Special Ecological Areas, their vulnerability to invasion and the cost of maintaining them can be expected to increase (Tunison and Stone 1992).

Impact of release of *T. ovatus* on the target weed is expected to advance gradually in time and area, providing long-term suppression of strawberry guava, allowing natural substitution of strawberry guava by other plant species, and preventing spread of strawberry guava into areas at risk from invasion. Acceleration of this process may be possible over selected areas by combining mechanical or herbicidal control with suppression by *T. ovatus*. Effective biological control of strawberry guava is expected to complement and benefit other weed management programs, for example, increasing the efficacy of mechanical removal of strawberry guava by slowing the weed's ability to resprout from surviving stems. To the extent that *T. ovatus* enhances conventional control of strawberry guava, land managers may find it environmentally and financially beneficial to use chemical or mechanical methods against this weed over larger areas of land. In these cases it may be appropriate to plan for active restoration of controlled areas, such as by introducing native species. The impacts of greater use of chemical or mechanical methods against strawberry guava would depend on the care taken to avoid damage and promote restoration of native ecosystems.

Mitigation Measures

As part of monitoring efforts, the U.S. Forest Service has a funded proposal to investigate the effectiveness of the interaction of biocontrol with other control methods. The U.S. Forest Service will make the results of this monitoring available to agencies, landowners and others in the interested public to promote responsible control methods.

No-Action Alternative

Under the no action alternative, the impacts of strawberry guava on native species would tend to accumulate with past and present invasive weed impacts and other factors that have degraded native forests over time. The long term cumulative impacts of failing to manage strawberry guava using biological control are expected by many scientists, land managers and environmental organizations to be highly adverse to biological resources in the State of Hawai‘i.

3.2 Agricultural and Economic Impacts

3.2.1 Commercial Use of Strawberry Guava, Wood and Plants

Action Alternative

Strawberry guava has modest commercial value. The fruit may be collected and eaten or made into juice and other products (Morton 1987). Farmers markets in Hawai‘i feature a wide variety of fruits and jams, but strawberry guava is almost never among them. Fruit flies are a very heavy pest on strawberry guava, which also spoil quickly after picking. A 2004 project in Kona, funded through the University of Hawai‘i Manoa College of Tropical Agriculture and Human Resources (CTAHR) and called “Twelve Fruits”, explored new fruits for potential commercial production in Hawai‘i. The study team attempted to determine if strawberry guava fruit could be a valuable commercial fruit crop. The group found that the fruits could be sold successfully at local markets, but the production was labor intensive and thus not economically viable. All fruits had to be bagged as they were growing to prevent infestation by fruit flies and damage by birds, and trees had to be pruned to a height conducive to bagging and picking. The effort was abandoned due to the noted invasiveness of the tree (Love et al 2007). At least one company on Maui produces small amounts (about 30 pints per year) of strawberry guava jelly using the fruits of just one tree (Frances Kinslow personal communication to Ron Terry, 2009).

Although the wood is used by some on a household level, as discussed in Section 3.5 below, for firewood for smoking meat, no commercial firewood or charcoal operation utilizing strawberry guava wood is known. Some craft implements and tools fashioned from strawberry guava are also sold commercially at stores and craft fairs. One local retailer in Hilo offers a makeshift fish-scaler made of strawberry guava wood and bottle caps. The plant is sometimes featured in gardens for its smooth multicolored bark contrasting with shiny, dark green leaves and toleration of pruning and shaping. However, the fruits are messy and attract insects, so planting next to sidewalks and driveways is discouraged. Potted plants and seed are sold by some horticulturalists in Hawai‘i, although this market is probably limited by the ubiquity of wild plants.

No substantial impact on the above-listed commercial uses of strawberry guava fruit, wood, or plants is expected. As discussed in previous sections, *T. ovatus* would not kill strawberry guava plants or taint their fruit. It slows fruit production and spread. The action will impact stands of guava gradually, allowing more native species to grow back and helping native forests to regenerate. People will still be able to pick fruit (even if will not be as abundant) and gather the wood, as Brazilians continue to do in their forests where the trees are preyed upon by a far greater multitude of insects. Furthermore, because this biocontrol agent has been thoroughly tested and found to be very specific to strawberry guava, it is highly unlikely that effects to any other plant product that might cause economic impacts would occur.

Mitigation Measures

For those who currently or in the future may wish to produce strawberry guava jellies or jams, the infestation of *T. ovatus* can be controlled by application of appropriate insecticides, which will reduce leaf galls. For example, the insect is susceptible to horticultural oil sprays, which are relatively innocuous to the environment and are compatible with production of fruit for consumption (Cranshaw and Day 1994). Neem oil and garlic oil, which can repel insects, inhibit their feeding, deter them from laying eggs, or retard their growth, are two natural botanical pesticides that are the least toxic to humans of various botanical pesticides such as citrus oils, mint oil, pine oil and herbal extracts.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and impacts to the minor commercial uses of the fruit of this plant could be avoided

3.2.2 Commercial Use of Native Forest Products

Action Alternative

Strawberry guava has a great impact on the viability of forestry operations using native trees. The native tree koa provides an attractive and extremely valuable hardwood used primarily in furniture, cabinets, crafts, and artwork. Silviculture of koa helps reduce the pressure on wild koa. Strawberry guava has been recognized as an impediment to sustainable wild koa harvests because many areas disturbed by logging are colonized by strawberry guava more quickly than by koa (Dobbyn 2003). It may completely limit koa to the overstory and prevent its regeneration (Baker et al. 2009). It is also a pest for commercial silviculture of koa, because it is difficult to remove from old agricultural land and is a pest in new plantings (Wade Lee personal communication to Ron Terry 2005). Unpublished data by Julie Denslow of the U.S. Forest Service indicates that site preparation costs can increase from $200-$300/acre for grass dominated acreage to $2,000/acre for acreage dominated by strawberry guava.

Mitigation Measures

No adverse impacts to the use of native forest products are anticipated from the proposed action and no mitigation measures are warranted.

No Action Alternative

Under the no action alternative, without the use of biocontrol of strawberry guava as a management tool on State lands, the continuing impact on koa operations could continue unabated.

3.2.3 Agricultural Damage Due to Fruit Flies

Action Alternative

Strawberry guava in Hawai‘i serves as a critical wild host of economically important fruit flies, including oriental fruit fly (*Bactrocera dorsalis*) and Mediterranean fruit fly (medfly, *Ceratitis capitata*) (Vargas et al. 1983a&b, Vargas and Nishida 1989, Vargas et al. 1990, Harris et al 1993). Pest populations developing in fruit from wild hosts, especially strawberry guava and *P. guajava*, overflow into dozens of fruit and vegetable crops. Economic costs associated with strawberry guava infestations in Hawai‘i are not well quantified, but appear to be substantial, as fruit flies are a major impediment to the production of soft fruits in Hawai‘i. For papaya alone, McGregor (2004) estimated that fruit flies cost growers $7.8 million per year due to reduced fruit quality and production, post production treatment for flies, and reduced export markets. Moreover McGregor (2004) estimated that fruit flies cost Hawai‘i $78 million in opportunity costs because fruit flies precluded the development of new production of soft-fruited crops. How much of that loss is attributable to strawberry guava is difficult to quantify, but Roger Vargas (USDA ARS PBARC) estimates that 95 percent of fruit fly populations can originate from wild common or strawberry guava stands. In windward wet climates, strawberry guava is the predominant host, providing breeding grounds for high populations of fruit flies that can attack orchard fruits up to five miles away.

The ubiquity of fruit flies also limits possibilities for export of Hawaiian produce to major markets such as California and Japan. Concern over accidental introduction of Hawai‘i’s fruit flies into the U.S. mainland costs millions of dollars annually in quarantine and eradication efforts (Kaplan 2004). A USDA-ARS area-wide pest management program has recently undertaken the task of integrating a variety of control tactics over large areas in Hawai‘i (Kaplan 2004). However, attempts at management of fruit fly pests are severely constrained by the abundance of fruiting strawberry guava (Vargas and Nishida 1989, Vargas et al. 1990, Vargas et al. 1995). Although biocontrol of strawberry guava is just a part of controlling fruit fly operations, the reduction of fruiting would provide a substantial benefit.

Mitigation Measures

The reduction in fruiting of strawberry guava that would result from the proposed action is in itself a substantial mitigation for damage to agriculture from fruit flies, and no mitigation measures are warranted.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and efforts to reduce the abundance and range of this species would be likely restricted to chemical and manual methods in limited areas, raising economic costs to agriculture related to fruit flies. In the absence of biological control of strawberry guava, the weed can be expected to increase in density in many agricultural areas and the magnitude of problems with pest fruit flies may increase.

3.2.4 Biomass Potential of Strawberry Guava

Action Alternative

It has also been suggested by some that stands of strawberry guava provide a potential untapped source of biomass energy whose integrity needs to be preserved as a sustainable resource for Hawai‘i. Chris Buddenhagen, former Coordinator of the Hawai‘i Invasive Species Council, and Scott Turn, of the Hawai‘i Natural Energy Institute, explored the potential for this use (personal communication to Anne Marie La Rosa, 2009). As a typical 25 megawatt biomass plant (some of which are in planning on various islands) could utilize up to 190,000 tons of dry strawberry guava per year, if economically feasible, requiring perhaps 7,000 acres of high density guava, the idea merited economic evaluation.

The calculations begin by assuming best case stocking densities of about 60,000 pounds per acre, found by Dr. Flint Hughes at the heavily infested Keauohana Forest Reserve on the Big Island. The energy value of guava was measured by Turn et al (2005) at 8,240 British Thermal Units (BTU) per pound. Out of various woods tested from Hawai‘i, including four species of eucalyptus, moluccan albizia, tropical ash, and ironwood, strawberry guava’s 8,240 BTU is close to the mean of 8,202 BTU (standard deviation 306 BTU) (Ibid).

Further assuming a high value of oil at $116 per barrel, the raw biomass value of strawberry guava wood on a per-acre basis would be approximately $9,850 (lower density stands would yield lower returns). This raw value, however, needs to be adjusted for the cost of harvesting, chipping and drying, and transporting. Unfortunately, harvest costs are very high even for stands of guava with adequate access. For conservation areas that are not immediately adjacent to roads, labor costs for harvest alone would be expected to exceed $10,000 per acre (see Section 2.3 above). Thus, even with high oil values, the biomass value of stands of strawberry guava would likely be net negative.

Many other species of trees would have higher value for biomass to energy conversion, which is one reason that no plant operator to date has proposed utilizing the abundant existing resources of strawberry guava for this purpose, preferring instead to propose fast-growing, high-BTU trees such as eucalyptus or tropical ash. For plantations, shrubs such as *Jatropha* spp. and grasses such as switchgrass and Guinea grass (*Panicum* spp.) are also far more attractive. Communication with companies proposing the use of biomass in Hawai‘i indicate that even if strawberry guava had appropriate energy characteristics, the fact that it is often located on steep slopes or away from roads disqualifies it from any serious consideration (Rory Flynn and John Ray, personal communication to Frances Kinslow and Ron Terry, 2009). Biomass operators look for crops that can be large in scale and rotational, with high cellulose content, proven performance, and ease of harvesting. Strawberry guava thickets do not offer these characteristics.

It should be noted that even after introduction of *T. ovatus,* huge stands of strawberry guava adjacent to roads will still be accessible and may, if desired, be harvested for biomass purposes. However, as discussed in Section 2.3, biomass harvesting as a control method for conservation is untenable. Natural area managers are most interested in managing low density outlier populations and invasion fronts in the most pristine areas, distant from roads, within a matrix of predominantly native and endemic species. While removal of strawberry guava for biomass fuel or material uses has been proposed as a way to defray the cost of control, this would only be feasible in areas close to roads (a small fraction of the total area). Removal of large amounts of biomass from remote areas would only be possible by helicopter, which would add far more cost than any potential value gained. Conservation work here would not combine well with a biofuels harvesting program.

Mitigation Measures

The proposed action would have almost no effect on the total biomass of existing stands of strawberry guava. The ability to harvest them for biomass, if desired, would not be affected. As there are any number of trees, shrubs and grasses with better biomass potential and little or no invasive species impacts, the future reduction of vigor in strawberry guava should not be considered an adverse impact to the biomass industry.

No Action Alternative

The no action alternative would likely increase future stocks of strawberry guava for use as a potential biomass feedstock, although there does not appear to be any substantial potential for this species as a feedstock with a positive net economic outcome.

3.2.5 Other Economic Issues

Action Alternative

The rapid growth of strawberry guava infestations also raises costs for vegetation management near roads, powerlines, homes, institutional buildings and businesses. Boundary and topographic surveyors are easily able to traverse most types of native forest but must cut strawberry guava with machetes, yielding sharp “punji sticks” that are a hazard until they have completely resprouted. Current costs of strawberry guava control in parks, watersheds and in road/utility corridors using herbicidal and mechanical methods are not well quantified but are likely to be considerable. The plant’s ability to resprout from cut or downed stems makes repeated control efforts necessary. Biocontrol that could slow the spread and growth of strawberry guava would likely yield substantial savings to these activities.

It was suggested in some comments during the original EA process that impacts to the value of private properties could be substantial if the biocontrol agent caused massive strawberry guava dieback or defoliation, inducing scenic impacts and loss of food and wood. As illustrated in Figure 2 and discussed below in Section 3.6 in the context of scenic impacts, the leaf galls on strawberry guava are effective at limiting growth and fruiting but are only visible from close-up, leaving a still attractive tree. Complete defoliation is very unusual in Brazil. The subtlety of impact of *T. ovatus* on strawberry guava is such that most residents would be unaware that the insect is feeding on individual strawberry guava trees. Considering these factors, it is highly unlikely that the proposed action would lead to the scale of scenic impacts that would devalue private property. Conversely, there might be minor increases in property values through the reduction in fruit fly pests, which gardeners and farmers may value.   In any case, there are many instances in which the State must balance the needs of its entire population and the State's resources as a whole with impacts to private properties. For example, the construction of new highways that serve the State's motorists invariably bring increases in noise, impacts to scenic vistas, and minor increases in air pollution. Only when impacts reach significant levels is compensatory mitigation to private property owners appropriate. Without this principle, the State would be unable to undertake its vital functions. The State of Hawai‘i has a duty to protect trust resources such as threatened and endangered species, which in this case carries with it minor sacrifices on the part of those who want to maximize the fruit production of this strawberry guava, a highly invasive species that is devastating native forests and the natural and cultural resources they contain.

Another area of economic concern is ecosystem services and ecotourism values provided by conservation lands, some of which are severely reduced by the impacts of strawberry guava. High densities of strawberry guava suppress regeneration of native species, alter the structure of the forest, increase evapotranspiration loss of water from the watershed (see Section 3.2, below), and reduce habitat for native birds and insects. Strawberry guava thickets reduce access of hikers and hunters to the forest and increase costs of trail maintenance. Abundant reproduction of strawberry guava from sprouts and seeds following control operations creates a perpetual need for intervention in subsequent years to maintain low population levels. The principal entities charged with the care of conservation lands in the State, such as DLNR, the National Park Service, the U.S. Fish and Wildlife Service, The Nature Conservancy, and Kamehameha Schools, lack the resources for long-term management of strawberry guava. Conservation land managers must practice a form of triage, abandoning some lands to the takeover of strawberry guava and restricting investments in weed control to a small percentage of the area designated for biodiversity conservation. The presence and abundance of strawberry guava on conservation lands reduces the likelihood that land is set aside for conservation purposes and may result in a *de facto* abandonment of declared conservation areas from further management. Costs of mechanical and chemical control of strawberry guava are highly variable, depending on the density of the infestation, accessibility of the site and rates of regrowth, as discussed in Section

2.3, above. Although it is difficult to estimate total economic losses from strawberry guava, they are likely substantial.

Mitigation Measures

The reduction in fruiting and vigor of strawberry guava that would result from the proposed action would substantially benefit vegetation management efforts and increase the ecotourism value and the value of ecosystem services provided by the native forests. It is difficult to definitively conclude that this reduction, along with the appearance of leaf galls on the plant, would not in any way affect the value of properties with strawberry guava, whether negatively (through decreased scenic value) or positively (through reduction in fruit fly pests). However, any such differences would be expected to be slight. In any case, the significant public benefits from this action must be considered as a mitigating factor outweighing these minor and speculative impacts.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and efforts to reduce the abundance and range of this species would be likely restricted to chemical and manual methods in limited areas, likely raising economic costs to vegetation management. As strawberry guava control over the vast majority of conservation areas by other means is infeasible, the loss to ecosystem services from continuing strawberry guava invasion is essentially inevitable. Under the no action alternative, impacts on the potential value of strawberry guava on private property could be avoided.

3.3 Soil Erosion, Watersheds, Public Health and Wildfire

Action Alternative

The forests of Hawaiʻi are important zones of water input that can be adversely affected by factors promoting soil compaction, erosion, or pollution. In general, ecologists conclude that maintaining the native forest in as pristine a condition as possible helps maximize groundwater recharge and the biota and water quality of Hawaiian streams. Hydrologic studies in Hawaiian forests show that the complex, layered structure of the native forests reduces the impact of rain on surface soils and minimizes the loss of surface soils. Monoculture forests of alien species do not provide this protection, greatly influencing hydrology (Giambelluca et al 2008). Forests of eucalyptus on Maui, loblolly pine at Kokeʻe on Kauaʻi, miconia on the Big Island, and strawberry guava statewide exhibit similar structural characteristics: a dense uniform canopy with very little understory. In native Hawaiian forests, the impact of raindrops is buffered by leaves of upper canopy trees such as ʻohiʻa and koa, and then again by leaves of subcanopy tress such as mehame, kopiko, hapu'u and kolea and again by epiphytes, ground ferns, mosses, and layers of decomposing branches and leaves. The forests also help block winds and retard evaporation (Science Daily, July 21, 2008).

Recent measurements in two tropical montane cloud forests in Hawai‘i indicate that invasion by strawberry guava reduces ground water recharge because of very high evapotranspiration rates (Giambelluca et al 2008). Compared with forest dominated by native ‘ohi‘a (*Metrosideros polymorpha*), a site heavily invaded by strawberry guava exhibited 27 percent higher evapotranspiration , with the difference rising to 53 percent during dry-canopy periods. Much of the difference may be due to the dense stand structure and high foliage biomass of strawberry guava invaded stands, suggesting that for many decades to come these forests will be diverting water that would otherwise recharge aquifers and streams. Expansion of dense stands of strawberry guava across island watersheds will result in further reductions of water to island water supplies.

Some comments on the biocontrol project expressed concern for increased risk of rockfall along roads and highways where strawberry guava helps hold the soil and rock, e.g., Hana Highway on Maui, and the Pali Highway on O‘ahu. If strawberry guava were removed suddenly and extensively from steep, wet areas without being replaced by other species, accelerated mass wasting, including rockfalls and landslides, could ensue. However, the impact of weed biocontrol agents on their target is not severe or rapid enough to promote such a sequence of events (Schooler et al. 2004). In the case of strawberry guava this scenario is particularly unlikely because *T. ovatus* has never been observed to kill even small potted plants under extremely high infestation levels. Even if trees were killed, the process would likely be so gradual that strawberry guava roots would continue to hold soil long until replaced by other plants.

At least one resident in public meetings expressed concerns that strawberry guava might be replaced with species that are more fire prone. The degree to which somewhat more fire-prone vegetation would be promoted by the proposed action is unknown, although ecologists consulted as part of the EA did not identify fire as a particular threat. As discussed in Section 3.1, there is a possibility that, within the rainforest, other invasive species such as palm grass or broomsedge may benefit from increased light availability within declining patches of strawberry guava. Although fires are very uncommon in the wet forests where strawberry guava is common, increases in grass density could conceivably lead to increased risk of wildfires during occasional droughts. The largest wildfires in Puna the last 30 years have been concentrated in the land makai of Highway 130 between Hawaiian Paradise Park and Hawaiian Beaches, where alien grasses have taken hold and ‘ohi‘a forest is largely gone. Wildfires are recognized as highly detrimental to Hawaiian ecosystems, because they eliminate native species and perpetuate systems dominated by fire-adapted alien grasses (Smith and Tunison 1992). Actions that help promote the health of the ‘ohi‘a forest, such as decreasing the amount of strawberry guava, are likely to help combat fire as well.

Mitigation Measures

The monitoring plan will include examination of vegetation change in various environments that can provide data on changing fuel loads and fire-prone vegetation, and suggest mitigation measures if warranted, to the question of whether the replacement vegetation might be more prone to fire.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land. Chemical and manual methods would likely not be effective on the landscape level on State land and would lead to continued lower recharge, and possibly greater sedimentation and even disease concerns. Strawberry guava often completely alters the ecology of the forest, becoming so dominant that it excludes all native trees. It is not known to what extent strawberry guava forests promote an increase in pigs, but pigs are often present. Their rooting activities, trampling and compaction and elimination can lead to increases in runoff, sedimentation and pathogens in the water. If pigs do increase as a result of strawberry guavas, a number of environmental impacts ensue. People using the forest or drinking or bathing in water downstream from the infestation area may be affected by serious zoonotic diseases (diseases that can pass between people and animals (Stephen Hess personal communication to Ron Terry, February 2009).

3.4 Cultural Resources

Rechtman Consulting, a Big Island-based cultural resources management firm, prepared a Cultural Impact Assessment (CIA) for the proposed action, with the assistance of the chief scientist for this EA and Frances Kinslow, B.A., of the U.S. Forest Service. The CIA is contained in full in Appendix 3 and summarized here. This study has been prepared pursuant to Act 50, approved by the Governor on April 26, 2000; in accordance with the Office of Environmental Quality Control (OEQC) *Guidelines for Assessing Cultural Impact*, adopted by the Environmental Council, State of Hawai‘i, on November 19, 1997; and in consideration of federal and state guidelines, among which are the Advisory Council on Historic Preservation's "Guidelines for Consideration of Traditional Cultural Values in Historic Preservation Review" (ACHP 1985); National Register Bulletin 38, "Guidelines for Evaluating and Documenting Traditional Cultural Properties"; the Hawai‘i State Historic Preservation Statute (Chapter 6E), which affords protection to historic sites, including traditional cultural properties of on-going cultural significance; and the criteria, standards, and guidelines currently utilized by the Department of Land and Natural Resources-State Historic Preservation Division (DLNR-SHPD) for the evaluation and documentation of cultural sites (cf. 13§13-275-8; 276-5).

Location

Unlike most CIAs, in which the typical project analyzed directly affects only a very limited area that can be systematically measured and described, the proposed biocontrol of strawberry guava would eventually affect all areas where strawberry guava occurs in the Hawaiian Islands, and in particular, locations where it occurs in the wild with some abundance (see Figure 1a).

Strawberry Guava Background

Strawberry guava was introduced to Hawai‘i in 1825 for use as an ornamental landscaping plant. As early as 1832, nurseries were selling strawberry guava seeds and trees in Hawai‘i for this purpose. There is no doubt that during the nineteenth century humans and animals alike consumed the fruit as well. As with common guava, strawberry guava was eaten raw and used for jams and jellies. Anthropologists studying Hawaiian household customs in the early twentieth century include “guava” among examples of food found in a typical household (MacCaughey 1917, Green and Beckwith 1928). As the species was not specified, this might have meant either, or both, common and strawberry guava. A book published by the University of Hawai‘i in 1936 encouraged Territory residents to eat strawberry guava and other commonly available fruits to make up for inadequacies in diet (Miller et al. 1936). The use of strawberry guava as a food source in Hawai‘i has likely not much changed since then. Many residents and visitors to Hawai‘i pick and eat fresh strawberry guava right from the tree, and jellies and jams are still produced at the household level. Strawberry guava is often cited as a favorite of children and is noted as a pleasant recollection of childhood for many Hawai‘i residents.

In addition, the wood, fruit, and leaves of this species are used for various activities and products, both modern and ancient in origin. In this latter category, the typically hard, straight trunk and branches of strawberry guava have been used as a substitute wood in the manufacture of hula and lua implements when native species cannot be obtained.

Another consideration is the feedback relationship that has developed between strawberry guava and feral pigs, with significant consequences for the proliferation of the former and a potential concomitant increase in the range of the latter. The populations of feral pigs which now roam the forests of Hawai‘i are descendants of the introduced and more aggressive European boars, which interbred with and eventually displaced the smaller Polynesian pigs (Burrows et al 2007). As discussed elsewhere in this EA, pigs have since developed mutual relationships with invasive species, whereby pigs forage on the invasive plants, and then carry the seeds to other areas of the forest.

As also discussed elsewhere, the most likely result of a reduction in strawberry guava fruits would be for pigs to consume other available foods. It is unlikely that any significant impact on pig populations would be observed, although localized reductions in populations may occur in some areas. Without discounting the importance of pigs for subsistence in Hawai‘i, it is important to also consider the well-documented negative impact that pigs have on native species, many of which have cultural uses.

Cultural impact assessments for fencing and ungulate removal projects have considered the relationship between pigs, strawberry guava, and cultural resources before. A CIA for the 1,264 acre Kapunakea Preserve on Maui concluded that, “Strawberry guava is a weedy tree spreading rapidly in the West Maui Mountains, in part, because of the foraging of feral pigs....[it] forms impenetrable thickets and develops strong root systems that can destroy the integrity of an archaeological site” (Gon 2008:12). Invasive vegetation control is always a concern when considering the long-term preservation of archaeological resources. On a roughly 350-acre section of land owned by Kamehameha Schools in the upland portions of Kahalu‘u Ahupua‘a in North Kona, strawberry guava was identified as one of the most significant threats to the roughly 3,500 archaeological features of the remnant agricultural fields documented on their property

(Rechtman Consulting 2004). The only techniques currently available for control of invasive vegetation in and around archaeological sites are herbicides and hand-clearing. Mechanized clearing is out of the question as it also results in the destruction of the archaeological features.

Healthy native forests abound in cultural resources. The uses of native wet and mesic forest plants in traditional Hawaiian culture, and their appearances in Hawaiian mythology, are extensive (see Kraus 1993). Many of the native trees, herbs, and ferns in the forest formerly provided or still provide flowers, leaves, wood, and sap for products such as hula implements and decoration, la‘au lapa‘au (medicinal plants), dyes for kapa, and countless other traditional products. However, the relationship goes deeper than simple exploitation of natural resources. In the traditional Hawaiian viewpoint, the natural and cultural, and the physical and spiritual, are not separate, but an integrated whole. Native plants represented the physical forms, or kinolau, of the ancestral deities called ‘aumakua. The upland forests, now some of the last refuge for native Hawaiian plants and animals, were once considered the dwelling place of the gods. These wao akua regions were sacred. Only individuals who had performed certain spiritual preparations could enter this realm, and then only for specific purposes. Taking care of the land, or malama ‘aina, therefore helps sustain the culture, and the integrity of the ahupua‘a, the forests and the watersheds from mauka to makai, is a critical part of this care. If lowland and mid-elevation rainforests of the Hawaiian Islands degrade into a virtual monoculture of strawberry guava, far more than biological diversity will be lost. Chants and mele that celebrate the sights, sounds and aromas of the forest will have meanings that can no longer be physically experienced.

Consultation

As part of the planning process for the proposed action, five public meetings were held, one each on O‘ahu, Maui, and Kaua‘i, and two on Hawai‘i Island, one in Kona and one in Hilo. Relative to potential cultural issues, public comments fell into two general categories: support for the proposed project on the grounds that the native forests (as cultural resources) need to be restored; and opposition to the proposed project (primarily heard on Kaua‘i) based on the fear that the reduction in strawberry guava will lead to a reduction in feral pig populations and thus have an effect on subsistence activities, namely the hunting of feral pigs. While most Hawaiian cultural specialists (see Burrows et al 2007) would agree that pig hunting was not a traditional cultural practice, hunting pigs for sport and for subsistence has become a customary practice for many Hawai‘i residents, independent of ethnic background. As Maly (2004) pointed out based on an extensive review of more than 60,000 native Hawaiian land documents dating between 1846 to 1910, “nearly every reference was in the context of them [pigs] being near-home and as being cared for (raised), not hunted.” While the CIA specifically did not identify pig hunting as a cultural practice, because it lacks an association with a specific ethnic or cultural group, the assessment recognized the potential secondary effects of the biocontrol action on pig hunting activities merit consideration in the context of socioeconomic impacts (see Section 3.5).

In recognition of the effects of strawberry guava on native forests and the natural and cultural resources contained therein, the CIA also incorporated a consultation process with native

Hawaiian cultural practitioners with connections to Hawai‘i's forest resources. Dawn Chang of Ku‘iwalu LLC conducted the consultations on several islands. Table 5 lists the individuals consulted.

Since its introduction to Hawai‘i roughly 180 years ago, strawberry guava has become known in Hawaiian as waiawī (the yellow variety) and waiawī ula‘ula (the red variety). None of the consultants identified any traditional cultural practices or belief associated with strawberry guava. While there was some discussion about the use of guava leaves for medicinal purposes, it was clearly the kuawa, or common guava, that was being referred to, not the strawberry guava.

Table 5
Cultural consultants

Name	*Association*	*Affiliation*	*Date*
Samuel Gon, III	Cultural practitioner	Nature Conservancy	3/23/09
Lloyd Case	Cultural practitioner/Subsistence hunter	Hawai‘i Wilderness Association	4/2/09
Leimana DaMate	Cultural practitioner	Aha Kiole Advisory Committee	4/2/09
Jonathan Scheuer	Land manager	OHA	4/16/09
Chuck "Doc" Burrows	Cultural practitioner	Ahahui Malama I Ka Lokahi	4/16/09
Kale Gumapac	Cultural practitioner	Kanaka Council	3/3/09
Ben Tajon	Cultural practitioner	Kanaka Council	3/3/09
Huihui Kanakaole	Cultural practitioner	Edith Kanakaole Foundation	5/5/09

It was noted that cultural practitioners, including hula and lua halau and woodcrafters, may use strawberry guava wood in the place of harder to acquire native species for the manufacture of certain implements. However, both Sam Gon and Doc Burrows commented that practitioners should be using the native woods rather than introduced woods, and that if strawberry guava is not controlled, there will be even fewer native woods available for cultural use. In a video prepared to provide information on biocontrol of strawberry guava, Sam Gon said:

> "As a conservation biologist, and a Hawaiian cultural practitioner, it breaks my heart to see these dark thickets of strawberry guava crowding out the native trees and plants that should be growing here….Strawberry guava has been in Hawai‘i so long and is so common in our forests that some people make use of it as a resource. Its wood can be used for hula implements and tools, and its fruits are edible. But as a Hawaiian cultural practitioner, I think strawberry guava is a sorry substitute for what we should be using for our implements and tools. We should be using our native trees: ‘ohi‘a, alahe‘e, lama, olopua, and dozens of other species that are being destroyed by a single foreign species" (Sam Gon, video interview, 2009). http://www.youtube.com/watch?v=-pAh-At0HdM

Lloyd Case and Leimana DaMate also stated that many people on the Big Island use strawberry guava wood for making smoke meat. Lloyd also expressed concerns as a subsistence pig hunter about the potential adverse impacts to the pig populations that may rely on strawberry guava as a food source.

All of the consultants expressed concerns regarding adverse impacts to native forest resources that will continue to occur as the result of the uncontrolled spread of strawberry guava. Jonathan Scheuer, speaking on behalf of OHA, felt strongly that if nothing is done now, the native forests in Wao Kele O Puna on the Big Island will be destroyed. OHA recently acquired Wao Kele O Puna and as cultural stewards of the land, has a kuleana or responsibility to ensure that the native forests are sustained and available for future generations. The cultural landscape of this and other native forests is a very significant resource which must be protected. While Huihui Kanakaole recognized the importance of protecting the native forests from invasive species, she stated that the Edith Kanakaole Foundation opposes the use of biocontrol measures, because they find no cultural basis in Hawaiian chants to support such a practice. Sam Gon and Doc Burrows spoke about protecting Hawai‘i’s native forests from invasive species so that cultural practitioners have resources to gather.

Sam Gon spoke about the ahupua’a land management concept and how everything is interconnected and interrelated from a Hawaiian cultural perspective. He shared that from his experience there is a visible difference in the water quality of streams in the vicinity of native forests as compared to forests comprised of non-native species. In the former instance the water is clean and clear and in the latter, the water appears dirty and murky.

As for the cultural appropriateness of the use of a biocontrol agent to manage strawberry guava, while all the cultural consultants agree that something needs to be done to protect the native forests to ensure that Hawaiians and others have access to exercise their traditional customary practices, and that the strawberry guava threatens the health of our native forests, there is some debate as to whether biocontrol is the culturally appropriate option. Kale Gumapac and Ben Tajon of Kanaka Council expressed concerns that all available options should exhausted before the use of biocontrol to manage the growth of strawberry guava. Huihui Kanakaole of the Edith Kanakaole Foundation would prefer that the approach focus on getting families to reconnect with the native forests so that they would exercise their kuleana to care for the resources. Sam Gon of the Nature Conservancy, Doc Burrows of the Aha Kiole Advisory Committee, and Jonathan Scheuer of the Office of Hawaiian Affairs see the problem as very urgent, and they are convinced that biocontrol is an appropriate measured response and the only effective means of controlling the growth of strawberry guava, which will afford the native forests a chance to recover. None of the cultural consultants suggested that strawberry guava thickets are a resource that should be saved; rather they expressed their differences on the approach for controlling its spread.

Identification of Cultural Resources, Practices, and Beliefs

The OEQC guidelines identify several possible types of cultural practices and beliefs that are subject to assessment. These include subsistence, commercial, residential, agricultural, access-related, recreational, and religious and spiritual customs. The guidelines also identify the types of potential cultural resources, associated with cultural practices and beliefs that are subject to assessment. Essentially these are natural features of the landscape and historic sites, including traditional cultural properties. A working definition of traditional cultural property is any historic property associated with the traditional practices and beliefs of an ethnic community or members of that community for more than fifty years. These traditions shall be founded in an ethnic community's history and contribute to maintaining the ethnic community's cultural identity. Traditional associations are those demonstrating a continuity of practice or belief until present or those documented in historical source materials, or both.

The origin of the concept of traditional cultural property is found in National Register Bulletin 38 published by the U.S. Department of Interior-National Park Service. "Traditional" as it is used, implies a time depth of at least 50 years, and a generalized mode of transmission of information from one generation to the next, either orally or by act. "Cultural" refers to the beliefs, practices, lifeways, and social institutions of a given community. The use of the term "Property" defines this category of resource as an identifiable place. Traditional cultural properties are not intangible, and they must have some kind of boundary. They are subject to the same kind of evaluation as any other historic resource, with one very important exception. By definition, the significance of traditional cultural properties should be determined by the communities that values them.

The definition of "Property" contains an inherent contradiction that complicates identification and evaluation of potential Hawaiian traditional cultural properties, because it is precisely the concept of boundaries that runs counter to the traditional Hawaiian belief system. The sacredness of a particular landscape feature is often cosmologically tied to landscape and all its other features. To limit a property to a specifically defined area may actually partition it from what makes it significant in the first place.

A further analytical framework for addressing the preservation and protection of customary and traditional native practices specific to Hawaiian communities resulted from the *Ka Pa'akai O Ka'āina* v Land Use Commission court case. The court decision established a three-part process relative to evaluating such potential impacts: first, to identify whether any valued cultural, historical, or natural resources are present; and identify the extent to which any traditional and customary native Hawaiian rights are exercised; second, to identify the extent to which those resources and rights will be affected or impaired; and third, specify any mitigation actions to be taken to reasonably protect native Hawaiian rights if they are found to exist.

Impacts of the Action Alternative and Mitigation Measures

During the course of this study there were no cultural resources, practices or beliefs identified to be directly associated with strawberry guava. There were no stands of strawberry guava identified as traditional cultural places, and a review of the ethnobotanical literature (i.e., Gutmanis 1976; Handy et al. 1972; Krauss 1993; Neal 1965; Palmer 2003) failed to identify any cultural uses of strawberry guava.

There is, however, a single strawberry guava tree located on the historic Walker Estate in Nuʻuanu that has been placed on Oahu's Exceptional Tree List. Trees are generally added to this list based on significant age and/or size, and owners receive a tax credit for the care of those trees. If this specific tree were to become infested with *T. ovatus*, it would not lead to mortality, but rather leaf galls and inhibited fruiting. If these effects occur, become noticeable, and are considered undesirable, the effects on *T. ovatus* on this single tree can be mitigated through the application of widely available horticultural oils, just as horticulturalists commonly apply to many landscaped ornamentals.

The action alternative will have no adverse impact on any cultural resources, practices or beliefs, and it will serve to enhance valued natural and cultural resources within Hawaiʻi's forested areas and beyond.

No Action Alternative

Conversely, when considering the areas that strawberry guava invades, many would agree that the native forests of all of Hawaiʻi's islands are part of a general cultural landscape; and thus, from an indigenous perspective and with respect to this study, should be considered a cultural property. The uncontrolled spread of strawberry guava throughout these areas can be seen as a significant cultural impact, particularly as it affects plants, animals and landscapes used for cultural practices.

Furthermore, strawberry guava has also invaded formerly forested areas that ancient Hawaiians cleared and used for agricultural practices, most significantly on Maui and Hawaiʻi islands. The threat to the archaeological resources of these areas from the spread of strawberry guava is enormous, both as a result of natural processes and during attempted mechanical control. The no action alternative would lead to continued cultural impacts and provides no mitigative relief for such impacts.

The no action alternative would have an unmitigated negative impact that would lead to continued degradation of Hawaiʻi's valued natural and cultural resources.

3.5 Socioeconomic Conditions

Action Alternative

Probably the comment that has been expressed most frequently concerning the effects of this biocontrol project is the potential to eliminate or severely reduce the beneficial uses of guava for households, particularly low-income households. Residents reported eating the fruit raw, using it in jams and jellies (some of which were traded or informally sold), chutney and even spaghetti sauce. In addition, the wood was reportedly used for firewood, charcoal, fruit poles, farming implements, fencing, cultural products such as hula sticks, and even bentwood furniture. One commenter reported that strawberry guava leaves can be used medicinally to treat diarrhea (although traditional diarrhea medicine usually involves common guava leaves, not strawberry guava). Of concern were the following potential impacts:

- Potential to reduce the quantity and to adversely affect the quality of strawberry guava fruit for human consumption;
- Potential to reduce the quantity and quality of wood that residents cite has a variety of uses: firewood, fruit poles, farming implements, medicine, cultural products, and furniture;
- Potential to eliminate the food source for animals that are valued for hunting, particularly the pig;
- The potential for these impacts to disproportionately affect low-income and minority populations, raising issues of environmental justice.

In reality, although *T. ovatus* reduces the vigor of the plant and is expected to reduce vegetative growth and fruit production substantially, there will still be abundant fruit, wood and leaves (the gall areas can simply be cut away or leaves without galls can be used). Considering the hundreds of thousands of acres with strawberry guava in conservation areas alone, even the estimated 60 to 90 percent reduction in fruiting and 25 to 40 percent reduction in vigor would leave enormous untapped resources of wood and fruit. Although residents see the fruit that emerges on isolated trees or shrubs and from the edges of thickets, most strawberry guava fruit is produced on the top branches of tall, narrow trees within the middle of the thickets. This fruit in the center of these thickets is not available for harvesting, and the wood of trees inside these “guava jails” is also not readily accessible for use.

As discussed in Section 3.1.2, above, wild pigs do make use of strawberry guava seasonally, but it is unlikely that the fruits are an essential part of their diet. A secondary human use of strawberry guava is the consumption of the fruit by feral pigs (*Sus scrofa*), which are hunted for their meat. Although pigs are omnivorous, studies of feral pig diets in Hawaiʻi have found that plant materials make up most of their diet. The diet is strongly influenced by habitat, and so a pig’s diet may be as little as 0 percent or as much as 70 percent sweet fruits such as papaya, passion fruit, and strawberry guava. Since fruits are seasonally available, the amount of fruit consumed is dependent on the season as well as location, and pigs are noted to move into different areas when fruits are available. The varied diet includes a significant consumption (over 50 percent of ferns and grasses, as well as earthworms and carrion for protein (Noguiera et al 2007). Pigs are omnivores and can utilize a variety of resources; high protein resources such as earthworms are preferred. Many high-elevation areas of Maui and the Big Island that lack strawberry guava are heavily infested with pigs, and it is unlikely that even a substantial reduction of strawberry guava fruit would have a major impact on pig populations. Because less dense stands of strawberry guava would promote better human access, it might even be possible that hunting success could be increased by the biocontrol action.

The expected reduction of density and strawberry guava monoculture should also have a beneficial impact on the ability to travel within the forest, whether for gathering for cultural purposes (as discussed in Section 3.4) or for hiking or birding. Strawberry guava thickets make it more difficult and expensive to create and maintain trails and recreation areas. Many comments at public meetings and to the original EA indicated that this would be highly beneficial.

Environmental justice is a term that refers to social inequity in bearing the burdens of adverse environmental impacts. Certain socioeconomic groups in the United States, including ethnic minorities and low-income residents, have historically experienced a disproportionate share of undesirable side-effects from locally undesirable land uses such as toxic waste dumps, landfills, and freeway projects (Cutter 1995). Executive Order (EO) 12898 requires federal agencies to take appropriate and necessary steps to identify and avoid disproportionately high and adverse effects of federal projects on the health and environment of minority and low-income populations. Because of the participation of the federal agency, the U.S. Fish and Wildlife Service, compliance with this order is necessary. In addition, in Act 294 of 2006, the Hawai‘i Legislature directed consideration of environmental justice concerns where there are disproportionate impacts on the environment, human health, and socioeconomic conditions of Native Hawaiian, minority, and/or low-income populations.

The action’s expected impact on strawberry guava trees, considered in light of the continuing availability of extremely large quantities of fruit and wood, the better forest access, the indeterminate and perhaps even positive impacts to hunting, and the cultural importance of native forest resources to Native Hawaiians, do not represent disproportionate impacts upon low-income and minority families and individuals.

Mitigation Measures

As discussed in Section 3.2.1 above, infestation of *T. ovatus* can be controlled at the household level by application of appropriate insecticides, including organic horticultural oil sprays that are compatible with production of fruit for consumption (Cranshaw and Day 1994).

No Action Alternative

Under the no action alternative, no biocontrol of strawberry guava would be attempted, and the efforts to reduce the abundance and range of this species would be restricted to chemical and manual methods that could only deal with limited areas. No reduction in fruit or wood would occur, but forest access in existing and expanded strawberry guava-dominated areas would be increasingly difficult.

3.6 Scenic Resources

Action Alternative

Comments at public meetings and in other channels revealed that many find strawberry guava an attractive plant, whether in yards or along roadsides. The dark green foliage and multi-colored bark can be striking. There is thus concern that *T. ovatus* may be damaging to the aesthetic value of scenic roadside or ornamental yard plantings of strawberry guava.

The leaf galls produced by *T. ovatus* in Brazil do not lead to severe defoliation or deformities in the tree, as shown in Figure 2, above. Severe defoliation would result mainly from an unusual combination of stresses such as prolonged drought (which would also affect most other plants). It is worthwhile to note that ‘ohi‘a, celebrated for its grace and beauty in Hawaiian songs and chants, exhibits leaf galls produce by a native co-evolved insect, without any loss of its general attractiveness. At the close-up scale (for example, if strawberry guava is used as a potted plant), however, the leaf galls may be perceived as unattractive. The majority of residents will be unaware that *T. ovatus* is feeding on individual strawberry guava trees, just as they are usually unaware that many other wild plants near their homes contain gall insects, as the effects are subtle unless individual branches and leaves are closely examined. Whereas there may be some decrease in the attractiveness of strawberry guava plants (reversible with the application of horticultural oil sprays), landscaping with islands of natural vegetation, which is highly attractive, will benefit from lessened competition from strawberry guava.
Other issues brought up during consultation were concerns about secondary scenic impacts – e.g., having strawberry guava replaced by less attractive non-native species, and the cumulative impacts to strawberry guava when added to the severe defoliation that has been produced by insects on wiliwili trees or pathogens on rose apple trees.

An invasive fungus called guava rust (*Puccinia psidii*), apparently introduced accidentally into Hawai‘i in 2005, infests a variety of plants in the myrtle family, including ‘ohi‘a, paperbark and rose myrtle, but affects rose apple most heavily (Anderson and Uchida 2008, Loope and LaRosa 2008). The rust produces bright yellow, spherical spores that easily become airborne. This has resulted in distribution of the disease to all major islands of Hawai‘i. Rose apple (*Syzygium jambos*) has been devastated, particularly moist windward sides of the islands. Newly-growing leaves are malformed and the trees appear sickly and unattractive.

Wiliwili (*Erythrina sandwicensis*) is an attractive red-flowered deciduous tree native to some of the driest parts of the Hawaiian Islands. An erect and leafy non-native variety was popular in landscaping as windbreaks and scenic barriers in both windward and leeward areas until the tiny invasive erythrina gall wasp (*Quadrastichus erythrinae*) began attacking wiliwili in 2005. So many galls are formed on the leaves, young stems, fruits and flowers that there is complete defoliation in the non-native variety. State officials released another tiny wasp that lays its eggs on the erythrina wasp in November 2008, and the effectiveness of this agent is currently being evaluated.

Importantly, the observed effects of *T. ovatus* on strawberry guava are not similar to those produced by the guava rust or erythrina gall wasp, as it rarely causes defoliation. Galls formed on strawberry guava leaves are comparable to those that naturally occur on ‘ohi‘a, which affect the plant’s metabolism but do not disfigure it. There will therefore likely be no adverse scenic effects to accumulate with those related to rose apple and wiliwili trees.

It should also be noted that many observers who are appreciative of native species and are concerned about the effects of strawberry guava find the plant an unattractive symbol of the devastation of the native forest and in fact would rather see native species such as ‘ohi‘a on roadsides. A reduction in strawberry guava, particularly if accompanied by an increase in native species, would enhance the scenic landscape for such individuals.

Mitigation Measures

As discussed in Section 3.5, the infestation of *T. ovatus* can be controlled at the household level by application of relatively innocuous insecticidal oil sprays (Cranshaw and Day 1994), which will reduce or eliminate leaf galls.

Another mitigation measure can be undertaken: to substitute other household or yard plants, such as native or non-invasive species, for strawberry guava. Nurseries sell a wide variety of such plants, and on various occasions such as Arbor Day and Earth Day, public institutions sell native trees at reduced prices or give them away.

No Action Alternative

Under the no action alternative, the biocontrol agent would not be released on State land, and potential scenic impacts could be avoided for those who find strawberry guava an attractive plant. The invasion of strawberry guava into native forests on State land would likely continue, causing scenic impacts for those who consider native plants to provide greater scenic value.

3.7 Consistency with Government Plans and Policies

3.7.1 Hawai‘i State Plan

Adopted in 1978 and last revised in 1991 (Hawai‘i Revised Statutes, Chapter 226, as amended), the Plan establishes a set of themes, goals, objectives and policies that are meant to guide the State’s long-run growth and development activities. The three themes that express the basic purpose of the *Hawai‘i State Plan* are individual and family self-sufficiency, social and economic mobility and community or social well-being. The proposed action is consistent with

State goals and objectives that call for preservation and restoration of natural, cultural and recreational resources.

The proposed action is in keeping with one of the goals in the Hawai‘i State Plan, which is maintaining stable natural systems, as stated in Section 226-4:

> In order to guarantee, for present and future generations, those elements of choice and mobility that insure that individuals and groups may approach their desired levels of self-reliance and self-determination, it shall be the goal of the State to achieve: ... (2) a desired physical environment, characterized by beauty, cleanliness, quiet, stable natural systems, and uniqueness, that enhances the mental and physical well-being of the people.

The action is also in keeping with the “overall direction” of the Plan, namely that of improving the quality of life through proper management of the State’s land resources, as presented in Section 226-102:

> The State shall strive to improve the quality of life for Hawaii’s present and future population through the pursuit of desirable courses of action in five major areas of statewide concern which merit priority attention: economic development, population growth and land resource management, affordable housing, crime and criminal justice, and quality education.

Discussion: The proposed action will help fulfill the goal of the plan by helping to restore stable natural systems, the uniqueness of which has been undermined by the invasion of strawberry guava. It fulfills the overall direction of the plan by contributing to management of land resources, namely native forests that are being degraded by invasion of strawberry guava.

Among the sections of the Hawai‘i State Plan most relevant to the proposed action are those centered on the theme of the physical environment.

The following objective and policies are taken from Section 226-11, which deals with land-based, shoreline and marine resources in the physical environment:

Objectives: Planning for the State’s physical environment with regard to land-based, shoreline and marine resources shall be directed towards achievement of the following objectives: (1) prudent use of Hawai‘i’s land-based, shoreline and marine resources and (2) effective protection of Hawai‘i’s unique and fragile environmental resources. To achieve those objectives, the Plan notes it shall be the policy of the state to:

(a) Exercise an overall conservation ethic in the use of Hawai‘i’s natural resources.

(b) Ensure compatibility between land-based and water-based activities and natural resources and ecological systems.

(c) Manage natural resources and environs to encourage their beneficial and multiple use without generating costly or irreparable environmental damage.

(d) Encourage the protection of rare or endangered plant and animal species and habitats native to Hawaii.

(f) Pursue compatible relationships among activities, facilities, and natural resources.

(g) Promote increased accessibility and prudent use of inland and shoreline areas for public recreational, educational, and scientific purposes.

And from Section 226-12, regarding the scenic, natural beauty, and historic resources of the physical environment:

Objective: Planning for the State's physical environment shall be directed towards achievement of the objective of enhancement of Hawai'i's scenic assets, natural beauty, and multi-cultural/historical resources. To achieve that objective, it shall be the policy of this State to:

(a) Promote the preservation and restoration of significant natural and historic resources.

(b) Provide incentives to maintain and enhance historic, cultural, and scenic amenities.

(c) Promote the preservation of views and vistas to enhance the visual and aesthetic enjoyment of mountains, ocean, scenic landscapes, and other natural features.

(d) Protect those special areas, structures, and elements that are an integral and functional part of Hawai'i's ethnic and cultural heritage.

Also relevant is Section 226-13, which concerns land, air and water quality of the physical environment:

Objectives: Planning for the State's physical environment with regard to land, air, and water quality shall be directed towards achievement of the following: (1) Maintenance and pursuit of improved quality in Hawai'i's land, air, and water resources, and (2) Greater public awareness and appreciation of Hawaii's environmental resources. To achieve those objectives it shall be the policy of the State to:

(a) Foster educational activities that promote a better understanding of Hawai'i's limited environmental resources.

(b) Promote the proper management of Hawaii's land and water resources.

(c) Reduce the threat to life and property from erosion, flooding, tsunamis, hurricanes, earthquakes, volcanic eruptions, and other natural or man-induced hazards and disasters.

(d) Foster recognition of the importance and value of the land, air and water resources to Hawai'i's people, their cultures and visitors.

Discussion: Hawai'i's natural resources continue to be threatened by the strawberry guava, which diminishes the scenic beauty, biodiversity and watershed values of the native forest. The proposed action would help protect rare and or endangered plant as well as animal species dependent upon native food and habitat. Once established, the dominance of the strawberry guava hampers accessibility and use of inland areas for public recreational, educational and scientific purposes. The action will help conserve the State's natural resources, namely native forests and ecosystems, thereby helping to protect rare and endangered plant species and habitats currently being overrun by the alien strawberry guava. The action also serves to educate both residents and visitors of the threat posed by invasive species to native environments and on the role biocontrol can play in controlling that threat.

Other sections of the Hawai‘i State Plan relevant to the proposed project are those centered on the theme of socio-cultural advancement. The following objective and policies are taken from Section 226-25 dealing with culture:

<u>Objective:</u> Planning for the State’s socio-cultural advancement with regard to culture shall be directed toward the achievement of the objective of enhancement of cultural identities, traditions, values, customs, and arts of Hawaii's people. To achieve the objective, it shall be the policy of this State to:

(a) Foster increased knowledge and understanding of Hawai‘i’s ethnic and cultural heritages and the history of Hawai‘i.

(b) Support activities and conditions that promote cultural values, customs, and arts that enrich the lifestyles of Hawai‘i’s people and which are sensitive and responsive to family and community needs.

(c) Encourage increased awareness of the effects of proposed public and private actions on the integrity and quality of cultural and community lifestyles in Hawai‘i.

The following objective and policies are taken from Section 226-23 regarding leisure and socio-cultural advancement:

<u>Objective:</u> Planning for the State’s socio-cultural advancement with regard to leisure shall be directed towards the achievement of the objective of the adequate provision of resources to accommodate diverse cultural, artistic, and recreational needs for present and future generations. To achieve the leisure objective it shall be the policy of the State to:

(a) Promote the recreational and educational potential of natural resources having scenic, open space, cultural, historical, geological, or biological values while ensuring that their inherent values are preserved.

(b) Ensure opportunities for everyone to use and enjoy Hawaii's recreational resources.

(c) Assure the availability of sufficient resources to provide for future cultural, artistic, and recreational needs.

(d) Assure adequate access to significant natural and cultural resources in public ownership.

Also relevant to the proposed project are the objective and policy from Section 226-27 pertaining to government and socio-cultural advancement:

<u>Objective:</u> Planning the State’s socio-cultural advancement with regard to government shall be directed towards the achievement of efficient, effective, and responsive government services at all levels in the State. To achieve that objective, it shall be the policy of this State to:

(a) Provide for necessary public goods and services not assumed by the private sector.

Discussion: The proposed action would help protect native plants and other resources that are traditionally collected and used for cultural purposes. Protecting those resources would further the Plan's desire to promote educational programs which enhance the understanding of Hawai'i's cultural heritage for residents and visitors alike. It will also improve access to non-urban areas used for recreational purposes by slowing the growth of strawberry guava which can form dense thickets that impede travel, thereby helping to increase the accessibility of those cultural resources.

Other relevant portions of the sections pertaining to socio-cultural advancement include §226-20, which calls for the fulfilling of basic individual health needs and maintaining environmentally healthful conditions in Hawai'i's communities through the prevention of contamination by pesticides and other potentially hazardous substances; and §226-21, which seeks the promotion of educational programs which enhance understanding of Hawai'i's cultural heritage. Also applicable is §226-8, objective and policies for the economy as it involves the visitor industry, which calls for the fostering of an understanding by visitors of the aloha spirit and of the unique and sensitive character of Hawai'i's culture and values.

Discussion: The action may reduce the need for herbicides to control the strawberry guava in many areas, but in other areas, combining the effects of biocontrol with additional mechanical and chemical control methods may prove effective. It is thus important that herbicides be applied carefully in conformance with State and federal laws. And as previously discussed, the effort will result in an increased understanding of the importance of native plants long used in native Hawaiian cultural activities.

The proposed action supports all relevant objectives and policies of the Hawai'i State Plan. It is worthwhile to note that although substantial reduction of fruiting will occur, there will still be abundant fruit and wood, and individual trees or shrubs can be protected from *T. ovatus* infestation using environmentally benign horticultural oil sprays, if desired.

3.7.2 Hawai'i County General Plan

The *General Plan* for the County of Hawai'i is a policy document expressing the broad goals and policies for the long-range development of the Island of Hawai'i. The plan was adopted by ordinance in 1989 and revised in 2005 (Hawai'i County Department of Planning). The *General Plan* itself is organized into thirteen elements, with policies, objectives, standards, and principles for each. There are also discussions of the specific applicability of each element to the nine judicial districts comprising the County of Hawai'i. Most relevant to the proposed project are the following Goals, Policies and Standards of particular chapters of the General Plan:

Environmental Quality – Goals

- Define the most desirable use of land within the County that achieves an ecological balance providing residents and visitors the quality of life and an environment in which the natural resources of the island are viable and sustainable.
- Maintain and, if feasible, improve the existing environmental quality of the island.

- Control pollution.

Environmental Quality – Policies

- Take positive action to further maintain the quality of the environment.
- Advise the public of environmental conditions and research undertaken on the island's environment.

Environmental Quality – Standards

- Pollution shall be prevented, abated, and controlled at levels that will protect and preserve the public health and well being, through the enforcement of appropriate Federal, State and County standards.
- Incorporate environmental quality controls either as standards in appropriate ordinances or as conditions of approval.
- Federal and State environmental regulations shall be adhered to.

Discussion: The proposed action will fulfill requirements of the Hawaiʻi County General Plan by maintaining, and, to a degree, improving the environmental quality of the island by slowing the spread of an invasive species threatening the quality of native forests.

Natural Beauty – Goals

- Protect, preserve and enhance the quality of areas endowed with natural beauty, including the quality of coastal scenic resources.
- Protect scenic vistas and view planes from becoming obstructed.
- Maximize opportunities for present and future generations to appreciate and enjoy natural and scenic beauty.

Discussion: The proposed action will slow the growth of an alien species which crowds out native forest plants, thereby helping to preserve the natural beauty of the island (in particular, that of its native forests) as set forth in this section of the Plan. Scenic impacts to hedgerows of strawberry guava will be minor, as the leaf galls do not disfigure the appearance of vegetation except from very close. The expected greater health and prevalence of native trees will produce scenic benefits.

Natural Resources and Shoreline – Goals

- Protect and conserve the natural resources from undue exploitation, encroachment and damage.
- Protect and promote the prudent use of Hawaii's unique, fragile, and significant environmental and natural resources.
- Protect rare or endangered species and habitats native to Hawaii.
- Protect and effectively manage Hawaii's open space, watersheds, shoreline, and natural areas.

Natural Resources and Shoreline – Policies

- Encourage a program of collection and dissemination of basic data concerning natural

resources.
- Coordinate programs to protect natural resources with other government agencies.
- Encourage public and private agencies to manage the natural resources in a manner that avoids or minimizes adverse effects on the environment and depletion of energy and natural resources to the fullest extent.
- Encourage an overall conservation ethic in the use of Hawaii's resources by protecting, preserving, and conserving the critical and significant natural resources of the County of Hawaii.
- Encourage the protection of watersheds, forest, brush and grassland from destructive agents and uses.
- Work with the appropriate State, Federal agencies, and private landowners to establish a program to manage and protect identified watersheds.
- Create incentives for landowners to retain and re-establish forest cover in upland watershed areas with emphasis on native forest species.

Natural Resources and Shoreline – Standards
- The following shall be considered for the protection and conservation of natural resources:
- Areas necessary for the protection and propagation of specified endangered native wildlife, and conservation for natural ecosystems of endemic plants, fish and wildlife.
- Lands necessary for the preservation of forests, park lands, wilderness and beach areas.

Discussion: The proposed action is designed to protect natural forests from encroachment by an invasive species. In the process it will manage and protect unique, fragile and significant natural resources, including watersheds and natural areas.

Land Use – Public Lands - Goal
- Utilize publicly owned lands in the best public interest and to the maximum benefit for the greatest number of people.

Land Use – Public Lands – Policy
- Encourage uses of public lands that will satisfy specific public needs, such as housing, recreation, open space and education.

Land Use – Public Lands - Standard
- Public lands with unique recreational and natural resources shall be maintained for public use.

Discussion: The proposed action fulfills the Plan’s Land Use section by helping to protect publicly owned lands with unique recreational and natural resources from further expansion by an alien species.

3.7.3 Kaua‘i County General Plan

The *General Plan* for the County of Kaua‘i is the document expressing the broad goals and policies for the long-range development and resource management for the Island of Kaua‘i. First adopted in 1971, the Plan was revised in 1984 and 2000. The *General Plan* is thematically arranged, discussing issues (in Chapters 3-8) including management of public facilities, preservation of rural character, and caring for land, water, and culture, among others. The General Plan also includes a chapter entitled "*Vision for Kaua‘i 2020*" that discusses roads, utility systems, and other public facilities and services.

Policies are summarized in two policy maps, a Land Use Map depicting policy for long-range land uses and a Heritage Resource map showing important historic, cultural and scenic resources discussed in the General Plan text. There are also discussions of the specific strategy for implementation for each policy element. The Plan's structure and content were the result of much public input and participation, including a public workshop involving about 3,000 citizens and 60 community groups, and also input from the Citizens Advisory Committee. Pertinent sections are presented below:

Native Hawaiian Rights – Policy

Under the State Constitution and the County Charter, the County of Kaua‘i is empowered to promote the health, safety and welfare of all inhabitants without discrimination as to ethnic origin. As part of carrying out its responsibilities under the Constitution and the Charter, the County recognizes the rights of native Hawaiians and the laws concerning lands and waters that have been established through the State Constitution, State and Federal laws, and State and Federal court decisions. No County ordinance or rule shall modify or diminish these rights:

- Traditional and customary rights of Native Hawaiians, such as for access and gathering, provided under the State Constitution and Hawai‘i Revised Statutes, as interpreted by the courts (i.e., the PASH case).

<u>Discussion:</u> The proposed action will help maintain a supply of native plants such as those gathered for cultural purposes.

Community Values

- Protection, management, and enjoyment of our open spaces, unique natural beauty, rural lifestyle, outdoor recreation and parks.
- Conservation of fishing grounds and other natural resources, so that individuals and families can support themselves through traditional gathering and agricultural activities.
- Access to and along shorelines, waterways and mountains for all. However, access should be controlled where necessary to conserve natural resources and to maintain the quality of public sites for fishing, hunting, recreation and wilderness activities valued by the local community.
- Recognition that our environment IS our economy, our natural capital, the basis of our economic survival and success.

- Respect and protection for the values and rights of our many cultures, in compliance with our laws and responsibilities as citizens.
- Appreciation and support for the visitor industry's role in preserving and honoring all cultures and their values as Kaua‘i’s leading source of income and as a supporter of community festivals, recreation, arts and culture.
- Protection of Kaua‘i’s unique character.

Discussion: The proposed action will help protect and manage the island’s natural beauty and resources and opportunities for traditional gathering for cultural purposes. It will also increase access by slowing the spread of thickets of strawberry guava. The result of these benefits will be protection of the environment and Kaua‘i’s unique character.

It should be noted that Kaua‘i General Plan defers responsibility for forest and natural area reserves and state parks, saying: “The State of Hawai‘i plays the preeminent role in managing natural resources....In addition to their value as forested watershed, these lands also harbor rare and endangered plant and animal species and areas where the native ecosystem remains relatively intact.” That section concludes: “In summary, the DLNR holds many responsibilities in caring for Hawai‘i’s special lands, waters, and cultural resources. In regulating land use on urban and agricultural lands, the County seeks expert advice from DLNR on aquatic and marine resources, streams, rare and endangered species, and historic and archaeological resources.”

Caring for Land, Waters and Culture
The Vision for Kaua‘i 2020 section of the Kauai County General Plan states:

> “The people of Kaua‘i, along with the State and County governments, practice careful stewardship of the island’s land and waters. The high mountains, forested watershed areas, the ocean and coral reefs, beaches – these areas are managed as part of the public lands trust. Over 50 percent of Kaua‘i’s land area lies in the undeveloped highlands of central Kaua‘i and the steep cliffs and valleys of the Na Pali Coast. Major landmarks include the peaks of Wai‘ale‘ale and Kawaikini; Waimea Canyon, and the Alaka‘i Swamp. Nurtured by careful conservation practices, these lands support recovering populations of native forest birds and other native plant and animal species…..
>
> Through planning and land use regulations, the County of Kaua‘i carefully safeguards its heritage of ecologically- and culturally-important lands, waters and sites. Through planning, the County identifies important resources and sets forth policies for responsible conservation and appropriate development. Zoning and other land use regulations are based on clearly defined policy and design objectives. The County avoids rigid land use formulas in favor of flexibility in achieving desired ends.”

Discussion: The proposed action will benefit the natural, cultural and scenic heritage of Kaua‘i.

3.7.4 Maui County General Plan

The *General Plan* for Maui County was originally adopted by ordinance in 1980 and revised in 1991. The Maui County General Plan 2030 is in draft form and is still under consideration by the Maui County Council. It is based on five themes: protecting Maui County's agricultural land and rural identity, preparation of a directed and managed growth plan, protecting Maui County's shoreline and limiting visitor industry growth, maintaining a viable economy that offers diverse employment opportunities for residents, and providing for needed resident housing. Described as a "statement of residents' needs and desires," the plan in its latest form incorporated recommendations from Decisions Maui, a program consisting of eight regional citizen teams from Molokai, Lanai and Maui, and other input from a series of community meetings across the county. The portions of the plan pertaining to the proposed action are as follows:

Land Use
<u>Objective:</u> To preserve for present and future generations existing geographic, cultural and traditional community lifestyles by limiting and managing growth through environmentally sensitive and effective use of land in accordance with the individual character of the various communities and regions of the County. Policies toward that end include:

- Identify and preserve significant historic and cultural sites.

<u>Discussion:</u> The proposed action will help protect and preserve native plants traditionally used by cultural practitioners.

<u>Objective:</u> To use the land within the County for the social and economic benefit of all the County's residents. Policies include:

- Mitigate environmental conflicts and enhance scenic amenities, without having a negative impact on natural resources.

<u>Discussion:</u> The proposed action will slow the incursion of strawberry guava that is impacting and dominating native forests.

Environment
<u>Objective:</u> To preserve and protect the county's unique and fragile environmental resources. Police to achieve that include:

- Preserve for present and future generations the opportunity to experience the natural beauty of the islands.
- Preserve scenic vistas and natural features.
- Support programs to reduce air, land and water pollution.
- Support programs to protect rare and endangered species and programs which will enhance their habitat.
- Discourage the introduction of noxious foreign species into Maui County's unique island ecosystems.

Discussion: The proposed action will slow the spread of the alien strawberry guava into unique island ecosystems containing rare and endangered species, helping to preserve the County's natural features.

Objective: To use the County's land-based physical and ocean-related coastal resources in a manner consistent with sound environmental planning practice. Polices include:

- Preserve, enhance and establish traditional and new environmentally sensitive access opportunities for mountain and ocean resources.

Discussion: The action will slow the spread of an invasive alien plant species which grows into thick, dense stands which inhibit access to forested areas.

Cultural Resources

Objective: To preserve for present and future generations the opportunity to know and experience the arts, culture and history of Maui County. Police toward that end include:

- Encourage the recordation and preservation of all cultural and historic resources, to include culturally significant natural resources.
- Establish programs to restore, maintain and interpret significant cultural districts, sites and artifacts in both natural and museum settings.
- Identify and maintain an inventory of significant and unique cultural resources for special protection.

Recreation and Open Space

Objective: To provide high-quality recreational facilities to meet the present and future needs of our residents of all ages and physical ability. Policies include:

- Maintain the natural beauty of recreational areas.

Objective: To provide a wide range of recreational, cultural and traditional opportunities for all our people. Policies that apply include:

- Encourage the use of public facilities for both cultural and recreational activities.
- Foster an increased awareness of the ethnic and cultural heritage of our people.
- Encourage the identification, restoration and preservation of important archaeological, historical and cultural sites.
- Encourage the use of public lands to expand and enhance outdoor recreational and cultural opportunities.

Discussion: Slowing the spread of the invasive plant will help preserve sources of native plants used in cultural activities, which in turn will foster additional awareness of those traditions. Recreational activities will be improved by slowing growth of strawberry guava which can impede access to natural areas.

Special Programs
Objective: To create a community in which the needs of all segments of the population will be recognized and met. Policies include:

- Support Federal, State and County programs and services designed to improve the general welfare and conditions of Native Hawaiians.

Government
Objective: Improve the delivery of services by government agencies to all community plan areas. Polices include:

- Support programs that will increase the overall effectiveness of government so as to provide greater responsiveness to the needs of our people.

Discussion: The proposed action, which will help preserve access to culturally important native plant materials, is supported by agencies of both the State and Federal governments.

3.7.5 City and County of Honolulu General Plan

The *General Plan* for the City and County of Honolulu is a planning document described as a "written commitment by the City and County government to a future for the Island of Oahu which it considers desirable and attainable." The plan has a two-fold mission: first, it is a statement of the long-range social, economic, environmental and design objectives for the general welfare and prosperity of the people of Oahu, and second, it is a statement of broad policies to facilitate attainment of those objectives. The plan contains 11 subject areas of public policy that include population, economic activity, the natural environment, transportation, public safety, culture and recreation and government operations. The plan was first adopted in 1977 and has been revised nine times since, concluding with the 1992 version which was further amended a decade later. The portions most relevant to the proposed project are as follows:

Natural Environment
Objective: To protect and preserve the natural environment. Policies to achieve that include:

- Seek the restoration of environmentally damaged areas and natural resources.
- Protect plants, birds and other animals that are unique to the State of Hawaiʻi and the Island of Oahu.
- Increase public awareness and appreciation of Oahu's land, air and water resources.

Objective: To preserve and enhance the natural monuments and scenic views of Oahu for the benefit of both residents and visitors. Policies include:

- Protect the Island's well-known resources: its mountains and craters; forests and watershed areas; marshes, rivers and streams; shoreline, fishponds and bays; and reefs and offshore islands.
- Protect Oahu's scenic views, especially those seen from highly developed and heavily traveled areas.
- Provide opportunities for recreational and educational use and physical contact with Oahu's natural environment.

Discussion: The proposed action would help fulfill the portions of the plan calling for restoration of environmentally damaged areas and natural resources, help protect unique plants and increase public awareness of threats posed by invasive species. By slowing the creation of dense stands of strawberry guava the action would help provide access opportunities to Oahu's natural environment.

Culture and Recreation

Objective: To foster the multiethnic culture of Hawai'i. Polices include:

- Encourage the preservation and enhancement of Hawai'i's diverse cultures.
- Encourage greater public awareness, understanding and appreciation of cultural heritage and contributions to Hawai'i made by the City's various ethnic groups.
- Encourage opportunities for better interaction among people with different ethnic, social and cultural backgrounds.
- Encourage the protection of the ethnic identities of the older communities of Oahu.

Objective: To protect Oahu's cultural, historic, architectural and archaeological resources. Polices include:

- Cooperate with the State and Federal governments in developing and implementing a comprehensive preservation program for social, cultural, historic, architectural and archaeological resources.
- Promote the interpretive and educational use of cultural, historic, architectural and archaeological sites, buildings and artifacts.
- Seek public and private funds, and public participation and support, to protect social, cultural, historic, architectural and archaeological resources.
- Provide incentives for the restoration, preservation and maintenance of social, cultural, historic, architectural and archaeological resources.

Discussion: The proposed action will help to preserve resources such as native plants used in cultural traditions thereby promoting their use and educational value and embracing Hawai'i's diverse cultural traditions.

3.7.6 Hawai'i Wildlife Action Plan

Hawaii's Comprehensive Wildlife Conservation Strategy (CWCS) is an interagency initiative that comprehensively reviewed the status of the full range of the State's native terrestrial and aquatic species (Mitchell et al 2005). The Hawai'i Department of Land and Natural Resources (DLNR) took the lead in preparing the CWCS. A combination of traditional outreach, such as public meetings and technical workshops, with 'modern' outreach, such as the development of a website and use of email, was used to invite and expand participation in the development of the CWCS. The collaborative nature of the effort, which involved resource managers, biologists, and concerned individuals statewide, indicates broad support and the likelihood that the conservation strategies identified will be implemented by multiple partners, including DLNR. Development of the CWCS allows as participation in the State Wildlife Grant (SWG) program administered by the U.S. Fish and Wildlife Service (USFWS). The CWCS of every state required the following eight elements:

1) Information on the distribution and abundance of species of wildlife identified as "species of greatest conservation need," including low and declining populations, as the State fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the State's wildlife;
2) Descriptions of the locations and relative condition of key habitats and community types essential to the conservation of species identified in (1);
3) Descriptions of problems which may adversely affect species identified in (1) or their habitats, and priority research and survey efforts needed to identify factors which may assist in restoration and improved conservation of these species and habitats;
4) Descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions;
5) Proposed plans for monitoring species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions;
6) Descriptions of procedures to review the plan at an interval not to exceed ten years;
7) Plans for coordinating the development, implementation, review, and revision of the plan with Federal, State, and local agencies and Indian tribes that manage significant land and water areas within the State or administer programs that significantly affect the conservation of identified species and habitats;
8) Provisions to ensure public participation in the development, revision, and implementation of projects and programs.

As part of the research and policy formulation, the CWCS determined the major threats facing Hawai'i's native wildlife are common to most species groups and habitats:

- Loss and degradation of habitat resulting from human development, alteration of hydrology, wildfire, invasive species, recreational overuse, natural disaster, and climate change;
- Introduced invasive species (e.g., habitat-modifiers, including weeds, ungulates, algae and corals, predators, competitors, disease carriers, and disease);
- Limited information and insufficient information management;
- Uneven compliance with existing conservation laws, rules and regulations;
- Overharvesting and excessive extractive use;
- Management constraints; and
- Inadequate funding to implement needed conservation actions.

To address these threats, the CWCS identifies multiple strategies to implement the following seven priority conservation objectives for the State:

1) Maintain, protect, manage, and restore native species and habitats in sufficient

quantity and quality to allow native species to thrive;
2) Combat invasive species through a three-tiered approach combining prevention and interdiction, early detection and rapid response, and ongoing control or eradication;
3) Develop and implement programs to obtain, manage, and disseminate information needed to guide conservation management and recovery programs;
4) Strengthen existing and create new partnerships and cooperative efforts;
5) Expand and strengthen outreach and education to improve understanding of our native wildlife resources among the people of Hawai'i;
6) Support policy changes aimed at improving and protecting native species and habitats; and
7) Enhance funding opportunities to implement needed conservation actions.

Successful implementation of the CWCS will require an ongoing effort of local, State, and Federal agencies, non-governmental organizations, private landowners, and individual citizens working together, as has occurred on the strawberry biocontrol project.

The plan references the invasive characteristics of strawberry guava in many contexts. It notes that:

> "Montane bog communities are particularly vulnerable to rooting pigs, and feral pigs contribute to the spread of habitat-modifying invasive plants such as strawberry guava (*Psidium cattleianum*) and kāhili ginger (*Hedychium gardnerianum*) in montane wet forest" (p.3-7).

Similar threats by strawberry guava to the lowland wet forest are discussed on page 3-8 of the CWCS. Strawberry guava makes the "short list of [nine] invasive plant species that pose a significant threat to native plant communities and require aggressive management" (p. 4-4).

In a summary of key habitat threats, where invasive plants are discussed, strawberry guava ranks as one of the four plants causing the greatest wildlife habitat degradation (p. 6-44). Accordingly, control of this invasive species, including biocontrol, are a key part of the statewide conservation objectives and strategies. Objective 2 is:

> *"Combat invasive species through a three-tiered approach combining prevention and interdiction, early detection and rapid response, and ongoing control or eradication."*

It is noted that continuous monitoring and responsive management are needed to prevent the establishment of invasive plants, algae, marine invertebrates, predators, parasites and pathogens in priority areas, and to control or remove invasive plant and animal species from areas managed for natural resources protection. One of the "High Priority Strategies" under this objective is:

> *"Continue to support research on biocontrol (including prescreening to limit unintentional secondary impacts) as one method that addresses priority invasive species."*

Cited specifically as a future need for both the Manuka and Kipahoehoe Natural Area Reserves is biocontrol for, among other species, fountain grass, Christmas berry, and strawberry guava (p. 6-80).

The plan also recognizes that insects used for biocontrol may interact with native insects through predation, competition or disease, hence the need for careful research of each potential biocontrol organism.

PART 4: ANTICIPATED DETERMINATION

Based on the information to this point, the Hawaiʻi State Department of Land and Natural Resources (DLNR) is expected to determine that the proposed project will not significantly alter the environment, in relation to the following criteria identified in the Hawaiʻi Administrative Rules § 11-200-12. It is therefore anticipated that an Environmental Impact Statement is not warranted and that the DLNR will issue a Finding of No Significant Impact (FONSI). A final determination will be made by the DLNR after consideration of comments on the Draft EA.

PART 5: FINDINGS AND REASONS

Chapter 11-200-12, Hawaiʻi Administrative Rules, outlines those factors agencies must consider when determining whether an action has significant effect.

1) Involves an irrevocable commitment to loss or destruction of any natural or cultural resource.
Uncontrolled strawberry guava is not a natural or cultural resource. Instead, the unnatural condition of lacking any type of predators has allowed it to become invasive to a degree that threatens survival of native forests and the diversity of the ecosystems they host, which are the true natural and cultural resources at risk. The action would help protect existing native forest, watershed and habitat for native plants and animals from invasion by one of Hawaiʻi's most destructive environmental weeds.

2) Curtails the range of beneficial uses of the environment.
The proposed action will not curtail beneficial uses of the environment. There will still be abundant fruit and wood (including potential biomass energy) from the enormous existing inventory of strawberry guava trees, which will simply experience a loss of vigor and a reduction in growth and fruiting. Instead, the release of *T. ovatus* is expected to substantially increase long-term beneficial uses of the environment by protecting native forests against degradation by invading strawberry guava and protecting agricultural activities from a major environmental source of non-native pest fruit flies.

3) Conflicts with the state's long-term environmental policies or goals and guidelines as expressed in Chapter 344, HRS, and any revisions thereof and amendments thereto, court decisions, or executive orders.
The proposed action is consistent with the environmental policies and guidelines established in Chapter 344, Hawaiʻi Revised Statutes (HRS) and contributes to the conservation of threatened and endangered species, as covered by Chapter 195D, HRS. It is also consistent with applicable goals of the four counties' General Plans, which include goals and policies for maintaining natural resources. Release of *T. ovatus* for biological control of strawberry guava is consistent with priorities identified in the Hawaiʻi Comprehensive Wildlife Conservation Strategy (2005), the Recovery Plan for the Big Island Plant Cluster (1996), the Draft Revised Recovery Plan for Hawaiian Forest Birds (2003), and the Three Mountain Alliance Final Management Plan (2007).

4) Substantially affects the economic or social welfare of the community or state.
The proposed action will not substantially affect the economic or social welfare of the community or state. It is expected to contribute to the economic and social well-being of local communities and the state through long-term improvement in the health of native forests and reduced impacts of pest fruit flies on Hawaiian agriculture. Healthy native forests offer recreational, cultural and watershed values that contribute to social welfare. It has been suggested by some that impacts to value of private properties could be substantial if the biocontrol agent caused massive strawberry guava dieback or defoliation, inducing scenic impacts and loss of food and wood. In reality, the leaf galls on strawberry guava are effective at limiting growth and fruiting but are only visible from close-up, leaving a still attractive tree. The majority of residents will be unaware that *T. ovatus* is predating individual strawberry guava trees. Considering these factors, it is highly unlikely that the proposed action would lead to the scale of scenic impacts that would devalue private property. In any case, there are many instances in which the State must balance the needs of its entire population and the State's resources as a whole with impacts to private properties. For example, the construction of new highways that serve the State's motorists invariable bring increases in noise, impacts to scenic vistas, and minor increases in air pollution. Only when impacts reach significant levels is compensatory mitigation appropriate. Without this principle, the State would be unable to undertake its vital functions, including protection of trust resources such as native forests and the natural and cultural resources they contain.

5) Substantially affects public health.
The proposed action is not anticipated to substantially affect public health in any adverse way. Strawberry guava trees will continue to be able to bear fruit, and *T. ovatus* is a scale insect that, like dozens of other such species already in Hawaiʻi, will not adversely affect people or their health. This insect spends almost all its life attached to a leaf without moving. Females cannot fly or even leave their galls; males are weak fliers that live only about 2 days and have never been known to swarm or bother humans in any way. Direct contact between humans and *T. ovatus* is likely to minimal because the insects are enclosed within leaf galls most of their lives. Humans near infested strawberry guava may experience chance contact with the eggs, crawlers and waxy filaments which emerge from female galls, but are unlikely to be aware of them because of their small size. *T. ovatus* cannot bite or sting and are not poisonous. Allergenicity of substances generated by homopterous insects is rare (Wirtz 1984). Among hundreds of species of soft scale insects around the world, including many very abundant pest species, allergic reactions are not known to be an issue. It appears very unlikely that *T. ovatus* poses any risk to human health.

6) Involves substantial secondary impacts, such as population changes or effects on public facilities.
No adverse secondary effects are foreseen. Impacts on agriculture, via reduced populations of pest fruit flies, are expected to be highly beneficial. Impacts on public utility rights-of-way are expected to be positive, in that slower growth of strawberry guava is expected to result in lower costs required for weed control under utility lines. Other benefits to public facilities can be

expected in the long term, since strawberry guava is expected to lessen in importance as an invasive weed as a result of biocontrol.

7) Involves a substantial degradation of environmental quality.
The proposed action does not involve a substantial degradation of environmental quality. Instead, the proposed action is expected to contribute to long-term protection of environmental quality associated with healthy native forests.

8) Is individually limited but cumulatively has considerable effect upon environment or involves a commitment for larger actions.
The proposed release of *T. ovatus* is expected to have direct effects limited to reduced growth and reproduction of strawberry guava, with impacts on this plant developing across the state over a period of decades. There are no other past, present, or reasonably foreseeable actions whose effects would contribute cumulatively to any adverse effects of this action. The proposed action does not involve commitment to larger actions because the impacts of the biocontrol agent are expected to be targeted and gradual.

9) Substantially affects a rare, threatened or endangered species, or its habitat.
Release of *T. ovatus* is expected to maintain and gradually improve the habitats of rare, threatened and endangered species that depend on native forest communities. By reducing growth and reproduction of strawberry guava, this action will protect native forests against degradation by invading strawberry guava.

10) Detrimentally affects air or water quality or ambient noise levels.
The proposed action will have no detrimental effects on air quality, water quality, or noise levels. Long term benefits to water quality are expected as a result of protecting forest health.

11) Affects or is likely to suffer damage by being located in an environmentally sensitive area such as a flood plain, tsunami zone, beach, erosion-prone area, geologically hazardous land, estuary, fresh water, or coastal waters.
The proposed action is not expected to adversely affect any environmentally sensitive areas, since impacts are expected to be gradual and should improve the stability of forest environments by favoring the persistence of native species over the invasive strawberry guava. The biocontrol agent and affected strawberry guava are not likely to suffer damage associated with environmentally sensitive areas because the affected forest areas are relatively stable inland environments.

12) Substantially affects scenic vistas and view planes identified in county or state plans or studies.
The proposed action is not anticipated to adversely affect any vistas or view planes identified in county or State plans or studies. Although individual plants will develop leaf galls (similar to those found on naturally on native plants such as ‘ohi‘a), the insect and its effects on strawberry guava are not expected to be noticeable to tourists and the general public.

13) Requires substantial energy consumption.
The proposed action does not require substantial energy consumption. The biocontrol agent will persist and spread gradually without any human assistance.

Issue of Uncertainty

Uncertainty regarding the consequence of a subject action requires evaluation as part of an EA. In the case of the proposed project, comments on the Federal EA and at public meetings have expressed concern about uncertainty regarding several aspects of the action, particularly as the results of releasing *T. ovatus* would likely be irreversible.

One concern relates to the possibility that *T. ovatus* would attack non-target plants. Historically, host shifts by introduced weed biological control agents to unrelated plants have been uncommon, and most importantly, highly predictable using standard methods for evaluating host-specificity. Since 1975, when three expert committees started reviewing all applications, host specificity has been 100 percent (Reimer 2002). However, if other plant species were fed upon by *T. ovatus*, the resulting effects could be environmental impacts that may not be easily reversed, and thus the slight possibility that it could move from the target plant (strawberry guava) to use non-target plants must be carefully considered. Host-specificity testing by the U.S. Forest Service and others indicates that, as would be expected with the very close interaction of *T. ovatus* and its host *P. cattleianum*, it is extremely unlikely that *T. ovatus* would use non-target plants. The narrow specificity of *T. ovatus* is also evident in Brazil where the insect is native and exposed to a broad diversity of plants, but only is found on *P. cattleianum* and one very close relative. A shift to a new host plant would require evolution of new traits, a process that might occur over a large interval of time. It should be recognized that the time scale of evolution is very long; at such scales, the thousands of other species of insects in Hawaiʻi have an equal opportunity to evolve new characteristics. Among the over 1,100 cases of weed biocontrol worldwide in the last century, rapid host range evolution to use non-target plants has never been documented. The successful history of modern biocontrol in Hawaiʻi, in which over 50 biocontrol species (including natural enemies for clidemia, banana poka, and ivy gourd) have been introduced to Hawaiʻi without any adverse effects, indicates that such risks are very small.

Another potential uncertainty relates to the degree to which *T. ovatus* will infest strawberry guava, and thus be both effective at controlling it and also severe in its impacts on fruiting and leaf galling. Based on infestations in Brazil, and the history of similar biocontrol projects involving single predators or pathogens, it appears likely that the effort will be moderately effective; i.e., enough galling to reduce fruiting and to slow growth. There is some possibility that *T. ovatus* will not infest to as high a degree or spread as rapidly as expected. If *T. ovatus* is more effective than expected, there will be a greater than expected loss of strawberry guava fruit but also a greater than expected benefit to the native forest, a tradeoff that on balance appears favorable for the trust resources of the State of Hawaiʻi.

In summary, there is no action that has consequences that are completely predictable, and thus there is uncertainty associated with any proposed action, including this one. Uncertainty must be weighed against potential benefits of an action and adverse impacts that are likely to occur if an action is not undertaken. In this case, there is a consensus among biologists in Hawaiʻi that strawberry guava is deleterious to the native ecosystem and that the risk of severe ecosystem damage is continually increasing. The uncertainty associated with biocontrol of strawberry guava appears to be low, due to the rigorous testing of this biocontrol agent and the general success of biocontrol projects in Hawaiʻi. Balanced against the certainty of the damage posed by continued growth of strawberry guava, the magnitude of its threat to Hawaiʻi's endangered species and ecosystems, and the urgent need for a more effective method for protecting these resources at risk, the levels of uncertainty associated with the proposed action appear acceptable.

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ENVIRONMENTAL ASSESSMENT

Biocontrol of Strawberry Guava by its Natural Control Agent for Preservation of Native Forests in the Hawaiian Islands

APPENDIX 1
Information on Host Specificity, Testing and Release Permit Conditions of *T. ovatus*

Index:

APPENDIX 1, Part 1
Biological Control Information

a. Taxonomy
Order: Homoptera Suborder: Sternorrhyncha Superfamily: Coccoidea Family: Eriococcidae
Genus: *Tectococcus* Species: *Tectococcus ovatus* Hempel

b. General description of *T. ovatus*
T. ovatus appears to cause substantial damage to strawberry guava in Brazil. Heavy infestations have been observed to cause defoliation and appear to reduce fruit production (Vitorino et al., 2000). It is also relatively easy to rear which facilitates careful evaluation of its specificity and increases likelihood of successful establishment in the field.

T. ovatus induces circular galls on leaves of strawberry guava. (A gall is an abnormal growth of plant tissues caused by the stimulus of another organism.) Galls up to 8 millimeters in diameter protrude from both sides of the leaf and are usually yellow to red in color. Each gall contains a single developing insect. Female galls are broadly conical, whereas male galls are smaller and narrower. Both have narrow openings at maturity for emergence of offspring or males. Females remain inside galls throughout life and are pink and ovoid with tiny legs. Adult males are pink to gold, have wings and are capable of weak flight.

T. ovatus is the only species in the genus *Tectococcus*. It is sufficiently unique that taxonomic specialists are not likely to confuse it with any other known scale insect species.

c. Geographical range of *T. ovatus* in area of origin
The insect was first collected and described from São Paulo and Ypirauga in Brazil (Hempel 1900). Origins of the insects proposed for environmental release in Hawai'i are from three municipal districts (Piraquara, São José dos Pinhais, and Colombo) in the metropolitan area of Curitiba, Paraná, Brazil (Vitorino et al. 2000).

T. ovatus has been observed to occur naturally in Parana and Santa Catarina states at sea level with mean annual temperatures of 18-22º C, and at approximately 1,000 meters elevation with mean annual temperatures of 15-19 º C (Vitorino 1995). There is no known evidence that *T. ovatus* has ever been exported outside its natural range previously.

d. Expected range of *T. ovatus* in Hawai'i
Populations of *T. ovatus* have been observed to persist continuously for over ten years in Curitiba, Brazil, where up to 40 mild to moderate frosts occur each winter. Because fluctuations in temperature and humidity are more extreme in subtropical Curitiba than in Hawaiian habitats where strawberry guava occurs (below 1,600 meters), climatic conditions in Hawai'i are not expected to limit the range of *T. ovatus* (Juvik and Juvik 1998).

e. Life history of *T. ovatus*
As with other scale insects, the mobile stage of *T. ovatus* is the newly hatched nymph or crawler. Crawlers typically move to flushing leaves at the tip of a stem and there become immobile, growing as galls form around them. Each female remains enclosed in a gall throughout its life, discharging up to several hundred eggs in a thread-like matrix of wax through a narrow opening. The cottony wax is extremely light and probably serves in dispersal by wind between plants (Vitorino et al., 2000). Reproduction is presumed to be facultatively parthenogenic (females can reproduce without mating with males). Multiple overlapping generations are observed each year in Brazil. Winged males appear at least twice a year (Vitorino et al. 2000). Mating has not been observed.

Under quarantine conditions in Hawai'i, *T. ovatus* reproduces continuously, with a generation time of 6-10 weeks. In two generations, numbers build to a level that causes stunting of small potted plants.

f. Known mortality factors of *T. ovatus*
In Brazil, *T. ovatus* can be heavily attacked by parasitoids (primarily *Metaphycus flavus*, Hymenoptera: Encyrtidae; less often, *Aprostocetus sp.*, Hymenoptera: Eulophidae) and a specialist predator (*Hyperaspis delicata*, Coleoptera: Coccinellidae). Although these enemies do not appear to strongly restrict *T. ovatus* population growth or limit impact on the host plant in Brazil (Almeida and Vitorino, 1997; Vitorino et al., 2000), their introduction to Hawai'i could compromise the effectiveness of *T. ovatus* for biocontrol of strawberry guava, and they could negatively impact non-target insects related to *T. ovatus* in the superfamily Coccoidea (relatives of *T. ovatus*), including native and non-native species (Zimmerman 1948). Elimination of hitch-hiking natural enemies is a standard practice in biological control programs (Balciunas and Coombs 2004). Adherence to this practice is expected to prevent introduction of enemies of *T. ovatus* to Hawai'i and is included among the permit conditions for release of *T. ovatus* specified by the Hawai'i Department of Agriculture (see below Part 6). Exclusion of unwanted species is accomplished in quarantine by initiating colonies with only *T. ovatus* eggs and newly hatched first instars, examined under a stereomicroscope, immediately after they emerge from female galls. Two generations of screening in this manner provides a check to guarantee that enemies are excluded.

APPENDIX 1, Part 3.
Host specificity of *Tectococcus ovatus* in no-choice (starvation) tests at Hawai'i Volcanoes National Park Quarantine Facility, 2002-2005, 2008-2009

Family (Subfamily)	Test plant species	Common names	No. of replicates	Total no. galls initiated	% Survival of nymphs[a]
Myrtaceae					
(Myrtoideae)	*Psidium cattleianum*	strawberry guava	37	383	44±13
	Psidium guajava L. variety:	common guava			
	Puerto Rico #2		2	0	0
	Waiakea		4	0	0
	Allahabad Safeda		2	0	0
	Fan Retief		2	0	0
	Ka hua kula		4	0	0
	Beaumont		2	0	0
	Thai maroon		3	0	0
	Eugenia brasiliensis	grumichama	2	0	0
	Eugenia reinwardtiana	nioi	3	0	0
	Eugenia uniflora	pitanga, Surinam cherry	5	0	0
	Myrciaria cauliflora	jaboticaba	5	0	0
	Feijoa sellowiana	pineapple guava	1	0	0
	Syzygium cumini	Java or jambolan plum	5	0	0
	Syzygium jambos	rose apple	6	0	0
	Syzygium malaccense	mountain apple	5	0	0
	Rhodomyrtus tomentosa	downy or rose myrtle	6	0	0
Myrtaceae					
(Leptospermoideae)	*Callistemon citrinus*	crimson bottlebrush	5	0	0
	Eucalyptus citriodora	lemon-scented gum	2	0	0
	Eucalyptus globulus	blue gum	5	0	0
	Melaleuca quinquenervia	paperbark	5	0	0
	Metrosideros macropus	ohia lehua	5	0	0
	Metrosideros polymorpha	ohia lehua	6	0	0
	Metrosideros rugosa	lehua papa	2	0	0
	Metrosideros tremuloides	lehua ahihi	2	0	0
Lythraceae	*Cuphea ignea*	cigar flower	1	0	0
	Lythrum maritimum	pukamole	2	0	0
Thymelaeaceae	*Wikstroemia sandwicensis*	akia	5	0	0
	Wikstroemia uva-ursi	akia	2	0	0
Brassicaceae	*Brassica oleracea*	kale	1	0	0
	Brassica rapa chinensis	bok choi	1	0	0
Caricaceae	*Carica papaya*	papaya	1	0	0
Malvaceae	*Theobroma cacao*	cacao	1	0	0
Sapindaceae	*Dodonaea viscosa*	a'ali'i	4	0	0
	Litchi chinensis	lychee	3	0	0
Cucurbitaceae	*Cucumis sativus*	Japanese cucumber	1	0	0
Moraceae	*Artocarpus altilis*	breadfruit	1	0	0
Fabaceae	*Acacia koa*	koa	3	0	0
	Sophora chrysophylla	mamane	4	0	0
	Phaseolus vulgaris	green beans	2	0	0
Proteaceae	*Macadamia ternifolia*	macadamia	2	0	0

Family (Subfamily)	Test plant species	Common names	No. of replicates	Total no. galls initiated	% Survival of nymphs[a]
Apiaceae	*Petroselinum crispum*	American parsley	2	0	0
Asteraceae	*Lactuca sativa*	manoa lettuce	1	0	0
Lamiaceae	*Ocimum basilicum*	green basil	2	0	0
Myoporaceae	*Myoporum sandwicense*	naio	4	0	0
Convolvulaceae	*Ipomoea batatas*	sweet potato	3	0	0
Rubiaceae	*Coffea arabica*	coffee	4	0	0
Lauraceae	*Persea americana*	avocado	3	0	0
Bromeliaceae	*Ananas comosus*	pineapple	1	0	0
Alliaceae	*Allium schoenoprasum*	chives	2	0	0
Araceae	*Colocasia esculenta*	taro (maui lehua)	1	0	0
Dicksoniaceae	*Cibotium glaucum*	hapu'u pulu	4	0	0

[a]Mean ± standard deviation.

APPENDIX 1, Part 4
Host specificity of *Tectococcus ovatus* in choice tests (insects could choose between test plants and *P. cattleianum*) at Hawai'i Volcanoes National Park Quarantine Facility, 1999-2001

Family (Subfamily)	Test plant species	Common names	No. of replicates	No. galls initiated on test plants	No. galls initiated on *P. cattleianum*
Myrtaceae					
(Myrtoideae)	*Psidium guajava* L.	common guava			
	Variety: Waiakea		3	0	20,17,27
	Ka hua kula		3	0	20,17,18
	Beaumont		5	0	20,18,6,55,32
	Syzygium jambos	rose apple	2	0	5,21
	Syzygium malaccense	mountain apple	2	0	10,9
Myrtaceae (Leptospermoideae)	*Eucalyptus citriodora*	lemon-scented gum	2	0	6,8
	Eucalyptus globulus	blue gum	2	0	9,9
	Lophostemon confertus	vinegar tree	2	0	10,90
	Melaleuca quinquenervia	paperbark	2	0	10,5
	Metrosideros macropus	ohia lehua	2	0	39,20
	Metrosideros polymorpha	ohia lehua	4	0	50,100,16,86
Lythraceae	*Cuphea hyssopifolia*	false heather	2	0	34,14
	Cuphea ignea	cigar flower	3	0	7,33,27
	Lythrum maritimum	pukamole	2	0	7,9
Thymelaeaceae	*Wikstroemia sandwicensis*	akia	2	0	9,16
Fabaceae	*Acacia koa*	koa	3	0	100,6,47
	Sophora chrysophylla	mamane	3	0	100,10,23
Anacardiaceae	*Rhus sandwicensis*	neleau	1	0	5
Sapindaceae	*Dimocarpus longan*	longan	3	0	7,8,30
	Dodonaea viscosa	a'ali'i	2	0	8,83
	Nephelium lappaceum	rambutan	3	0	7,8,30
Myoporaceae	*Myoporum sandwicense*	naio	2	0	85,11
Rubiaceae	*Coprosma rhynchocarpa*	pilo	2	0	20,44
Dicksoniaceae	*Cibotium glaucum*	hapu'u pulu	2	0	34,12

APPENDIX 1, Part 5. Results of *Tectococcus ovatus* host specificity testing at the University of Florida, 2003-2005

Test Plant	*Family*	*Gall development*	*Replications*
Psidium cattleianum var. *lucidum* Sabine	Myrtaceae	+	50
Psidium cattleianum var. *cattleianum* Sabine	Myrtaceae	+	3
Psidium friedrichsthalianum O. Berg	Myrtaceae	-[a]	3
Psidium guineense Sw.	Myrtaceae	+[b]	3
Psidium guajava L.	Myrtaceae	-	3
Acca sellowiana (O. Berg) Burret	Myrtaceae	-	3
Eugenia axillaris (Sw.) Willd.	Myrtaceae	-	3
Eugenia foetida Pers.	Myrtaceae	-	3
Eugenia uniflora L.	Myrtaceae	-	3
Myrciaria cauliflora (C. Martius) O. Berg	Myrtaceae	-	3
Pimenta dioica (L.) Merr.	Myrtaceae	-	3
Pimenta racemosa (P. Mill.) J.W. Moore	Myrtaceae	-	3
Syzygium malaccense (L.) Merr. & Perry	Myrtaceae	-	3
Syzygium paniculatum Gaertner	Myrtaceae	-	3
Callistemon citrinus (Curtis) Staph	Myrtaceae	-	3
Callistemon viminale (Gaertn.) G.Don ex Loudon	Myrtaceae	-	3
Eucalyptus camaldulensis Dehnhardt	Myrtaceae	-	3
Leptospermum scoparium J.R. & G. Forst.	Myrtaceae	-	3
Melaleuca quinquenervia (Cav.) Blake	Myrtaceae	-	3
Calyptranthes pallens Griseb.	Myrtaceae	-	3
Calyptranthes zuzygium (L.) Sw.	Myrtaceae	-	3
Eugenia confusa DC.	Myrtaceae	-	3
Eugenia rhombea Krug & Urban	Myrtaceae	-	3
Mosiera longipes (Berg) McVaugh	Myrtaceae	-	3
Myrcianthes fragrans (Sw.) McVaugh	Myrtaceae	-	3
Ammannia coccinea Rottb.	Lythraceae	-	3
Cuphea hyssopifolia Kunth	Lythraceae	-	3
Cuphea micropetala Humb., Bonpl. & Kunth	Lythraceae	-	3
Decodon verticillatus (L.) Ell.	Lythraceae	-	3
Lagerstroemia indica L.	Lythraceae	-	3
Lythrum alatum Pursh	Lythraceae	-	3
Rhexia lutea Walt.	Melastomataceae	-	2
Rhexia mariana L.	Melastomataceae	-	3

"+" indicates feeding damage and gall development; "-" indicates a lack of feeding damage and gall development (Wessels et al. 2007).

APPENDIX 1, Part 5, continued

Test Plant	*Family*	*Results*	*Replications*
Rhexia nashii Small	Melastomataceae	-	3
Tetrazygia bicolor (P. Mill.) Cogn.	Melastomataceae	-	3
Rollinia mucosa (Jacq.) Baill.	Annonaceae	-	3
Punica granatum L.	Punicaceae	-	2
Conocarpus erectus L.	Combretaceae	-	3
Chrysobalanus icaco L.	Chrysobalanaceae	-	3
Nyssa sylvatica var. *biflora* Walt.	Nyssaceae	-	3
Daphnopsis americana (P. Mill.) J.R.	Thymelaeaceae	-	3
Ilex cassine L.	Aquifoliaceae	-	3
Ilex x *attenuata* Ashe	Aquifoliaceae	-	3
Delonix regia (Bojer ex Hook) Raf.	Fabaceae	-	3
Quercus hemisphaerica Bartr. ex Willd.	Fagaceae	-	3
Persea americana P. Mill.	Lauraceae	-	3
Ficus aurea Nutt.	Moraceae	-	3
Myrica cerifera (L.) Small	Myricaceae	-	3
Saccharum officinarum L.	Poaceae	-	3
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	-	3
Prunus angustifolia Marsh.	Rosaceae	-	3
Prunus persica (L.) Batsch	Rosaceae	-	3
Pyrus x *lecontei* ‘Hood’	Rosaceae	-	3
Citrus limon (K.) Burm. F.	Rutaceae	-	3
Citrus x *paradisi* Macfad.	Rutaceae	-	3
Citrus sinensis (L.) Osbeck	Rutaceae	-	3
Taxodium distichum (L.) L.C.	Cupressaceae	-	3
Pinus elliottii Engelm.	Pinaceae	-	3
Podocarpus macrophyllus (Thunb.) Sweet	Podocarpaceae	-	3

[a] *T. ovatus* survived longer than the 2 week test period; test was extended to 4 weeks, but no damage or gall formation was observed.

[b] *T. ovatus* survived longer than the 2 week test period; test was extended to 4 weeks, weak leaf gall formation was observed.

APPENDIX 1, Part 6. Import Permit Conditions for *Tectococcus ovatus* established by the Hawai'i Department of Agriculture Plant Quarantine Branch in 2007

1. The restricted article(s), *Tectococcus ovatus,* shall be used for field release as authorized by the Plant Quarantine Branch (PQB).

2. The permittee(s), Dr. M. Tracy Johnson, shall be responsible and accountable for all restricted article(s) imported, from the time of their arrival to their disposition.

3. The restricted article(s) shall be safeguarded at the Permittee(s)' facility located at the Quarantine Facility, Hawai'i Volcanoes National Park, which has been inspected and approved by the PQB prior to importation.

4. The permittee(s) shall submit samples of the restricted article prior to importation to the PQB, which will be placed in the Hawai'i Department of Agriculture Insect Quarantine Facility of the Hawai'i Volcanoes National Park Quarantine Facility for screening for other species, predators, parasites, parasitoids or hyperparasitoids for a minimum of two generations. A report shall be submitted to PQB of any organisms found other than the restricted article(s).

5. All parcels containing the restricted article(s) that are imported into the State shall be clearly marked: "May be opened and delayed for agricultural inspection in Hawai'i".

6. An invoice, bill of lading, or other document shall accompany each shipment listing the scientific name and quantity of each restricted article(s) imported.

7. All parcels containing the restricted article(s) shall be subject to inspection by the PQB prior to entering the State and shall be imported through an approved port-of-entry as designated by the Board of Agriculture.

8. The imported restricted article(s) and the permittee(s)' facility shall be made available for inspection by the PQB or other designated Hawai'i Department of Agriculture employee(s).

9. The permittee(s) shall submit a report to the PQB on results of post-release monitoring programs on a semi-annual basis.

10. The permittee(s) shall immediately report any theft, accidental release, or disease outbreaks involving the restricted article(s) to the PQB at (808) 832-0566.

11. The permit is subject to revocation and all restricted article(s) and materials that came into contact with the organism may be subject to confiscation should any of the restricted article(s) or infected materials be removed from the approved facilities without authorization from the PQB prior to removal.

12. The permit is subject to cancellation for violation of permit conditions upon written notification from the PQB. A canceled permit is invalid and all article(s) listed on the permit shall not be imported.

13. The permittee(s) shall agree in advance to defend and indemnify the State of Hawai'i, its officers, agents and employees for any and all claims against the State of Hawai'i, its officers, agents, or employees that may arise from or be attributable to any of the restricted article(s) that are introduced under this permit. This permit condition shall not apply to a permittee that is a federal or State of Hawai'i entity or employee, provided that the State or federal employee is a permittee in the employee's official capacity.

14. This permit or conditions of this permit are subject to cancellation or amendment at any time due to changes in administrative rules restricting or disallowing import of the restricted article(s) or due to Board of Agriculture action disallowing a previously permitted use of the restricted article(s).

APPENDIX 1, Part 7
Permit Conditions for Environmental Release of *Tectococcus ovatus* established by USDA Animal and Plant Health Inspection Service, issued April 4, 2008

This permit is issued to Dr. Matthew Johnson, USDA Forest Service, Hawaii Volcanoes National Park Quarantine Facility, and authorizes the movement of the biological control organism, *Tectococcus ovatus*, from quarantine and also authorizes environmental release in Hawaii.

1. Plant feeding biocontrol agents and natural enemies of plant pests are regulated by USDA under the authority of the Plant Protection Act of 2000. This permit authorizes the interstate movement of organisms listed on the PPQ Form 526 (henceforth referred to as approved organisms) to the designated state for release into the environment.
2. Approved organisms are to be shipped in sturdy escape-proof containers.
3. No seeds or propagative host plant parts are to be included in the shipments of approved organisms.
4. All host material accompanying approved organisms in shipments must be destroyed or sterilized prior to disposal.
5. This permit does not relieve the permittee of the obligation to comply with regulations of other state and Federal agencies.
6. Issuance of this permit constitutes neither a certification nor an endorsement by USDA/APHIS of the quality, efficacy or any other potential product claim related to the commercial value or effectiveness of products derived from issuing this permit.
7. Permittee moving field collected organisms must take all precautions to prevent shipping of unidentified species and diseased or parasitized individuals to prevent the movement of contaminant organisms.

ENVIRONMENTAL ASSESSMENT

Biocontrol of Strawberry Guava by its Natural Control Agent for Preservation of Native Forests in the Hawaiian Islands

APPENDIX 2
Cost Estimates for Manual/Herbicide Control of Strawberry Guava

Estimating the Cost of Controlling Strawberry Guava in East Hawaii Conservation Areas

Assumptions

- Labor costs are estimated at $15 per hour plus benefits for $200 per worker day
- Based on consultation with resource managers experienced in control of forest weeds (including Strawberry Guava), we conservatively estimate dense infestations to take about 50 worker days per acre and incipient invasions (scattered trees) to take about one worker day per acre
- Control methods include cutting all stems of Strawberry Guava and applying herbicide to prevent resprouting. Control of the numerous seedlings and any subsequent growth would occur during a secondary sweep of each control area.
- Because only a few areas are easily accessible by road, we considered extra costs associated with work in more remote areas. Away from roads, workers would need to carry equipment through dense vegetation and over rugged terrain. Areas more than 0.5 km (0.3 miles) require extra time for work crews to access and therefore a higher cost per acre. Areas more than 2.5 km (1.5 miles) are too remote to work on a day by day basis (too much time would be spent getting to and from access points along roads); therefore these areas would require work crews to camp and would likely involve helicopter transport for equipment and camping gear.
- Costs were broken down according to the severity of the infestation and the distance from roads (see Tables 1 and 2). Maps of these attributes were combined in a Geographic Information System (GIS) in order to determine how much area has a given combination of characteristics (see Maps 1 through 4).

Estimated Costs

Incipient Invasions

Near roads: 31,600 acres × $250/acre = $7,900,000

Moderate Distance: 86,800 acres × $284/acre = $24,651,000

Remote: 61,300 acres × $506/acre = $31,018,000

Dense Infestations

Near roads: 9,200 acres × $10,500/acre = $96,000,000

Moderate Distance: 11,900 acres × $12,200/acre = $145,180,000

Remote: 2,700 acres × $23,315/acre = $62,950,000

Total Cost: $367,700,000

Additional Considerations

- While removal of Strawberry Guava for biomass fuel or material uses has been proposed as a way to defray the cost of control, this would only be feasible in areas close to roads (a small fraction of the total area). Removal of large amounts of biomass from remote areas would only be possible by helicopter which would add far more cost than any potential value gained.

- Building of additional roads for access is not considered feasible due to added costs and the legal limitations of road construction in areas zoned for conservation or designated as endangered species habitat.

- Because Strawberry Guava produces numerous seeds, a secondary sweep (after perhaps 3-4 years) of each treated are would be necessary to control seedlings. This would likely incur a cost similar to that for incipient invasion across the entire region (estimated at about $70,000,000 total for the secondary sweep). Continued dispersal from non-controlled areas may require additional sweeps near the boundaries of controlled areas, adding an unknown cost.

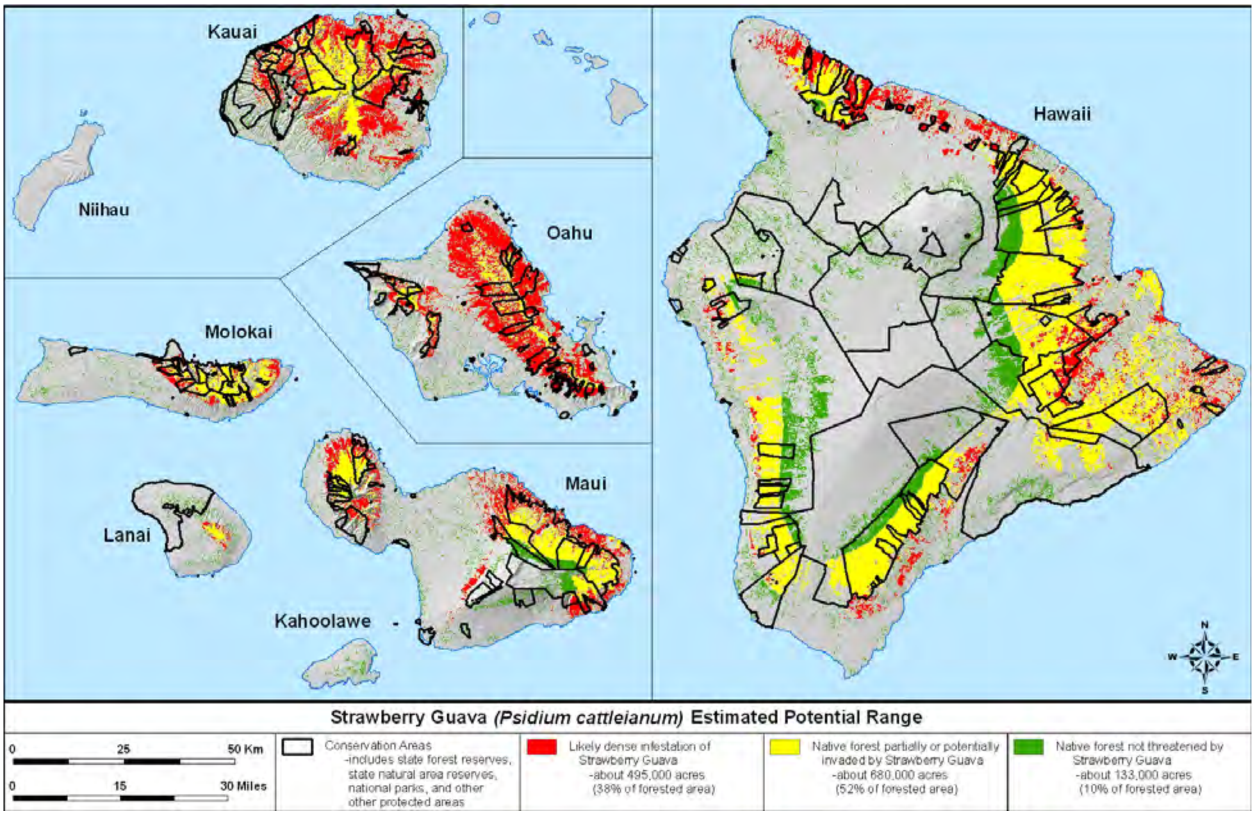
Table 1. Cost per Acre for Control of Incipient Invasion

	Labor	Equipment	Additional	Total
Close to roads (within 0.3 mi or 0.5 km)	1 worker day × $200/day = $200	$50	0	$250
Walking distance from roads (.5-2.5 km or 0.3-1.5 mi)	1.17 worker days × $200/day = $234	$50	0	$284
Remote/Helicopter >2.5 km/1.5 mi	1.46 worker days × $200/day = $292	$50	$164	$506

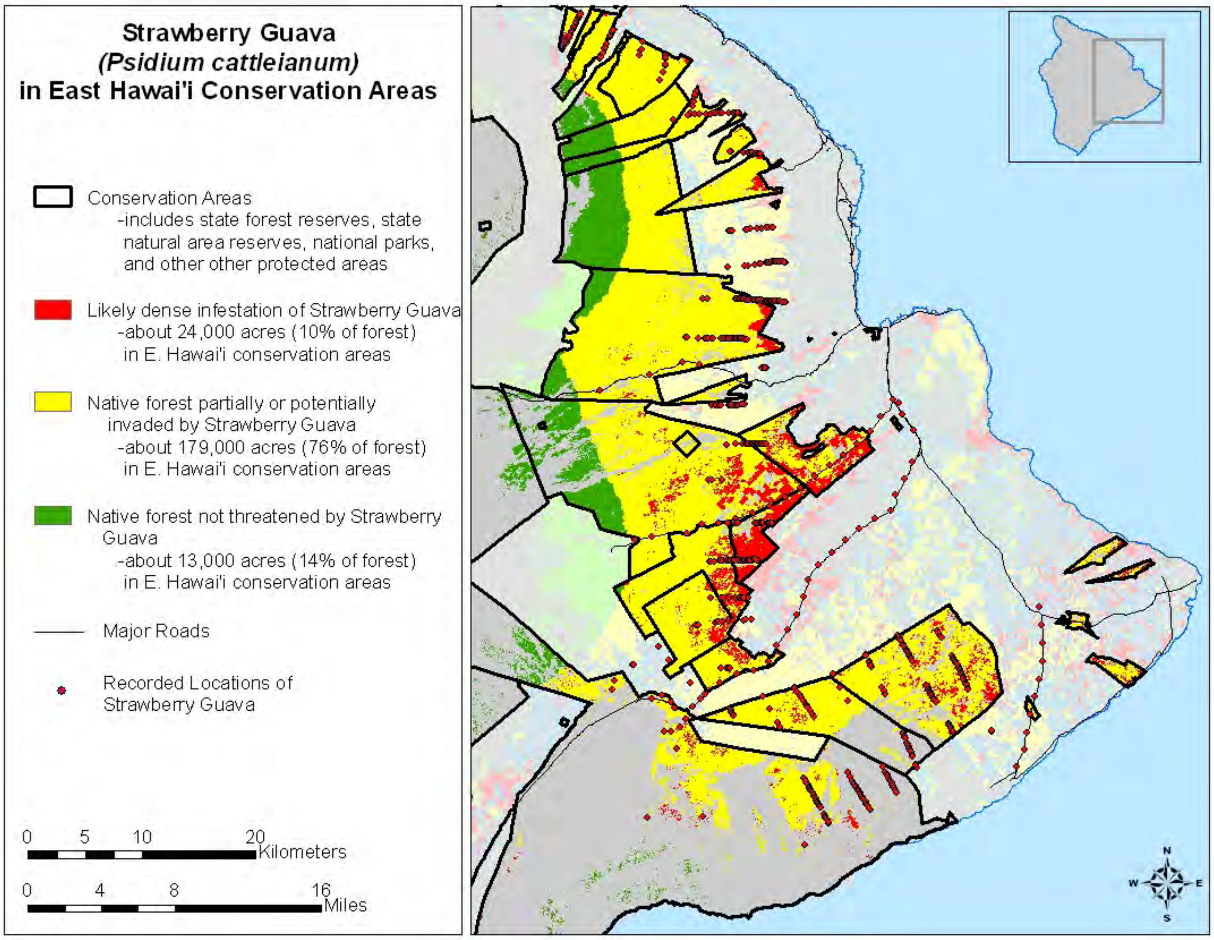
Table 2. Cost per Acre for Control of Dense Infestation

	Labor	Equipment	Additional	Total
Close to roads (within 0.3 mi or 0.5 km)	50 worker days × $200/day = $10,000	$500	0	$10,500
Walking distance from (.5-2.5 km or 0.3-1.5 mi)	58.5 worker days × $200/day = $11,700	$500	0	$12,200
Remote/Helicopter >2.5 km/1.5 mi	73.1 worker days × $200/day = $14,625	$500	$8,190	$23,315

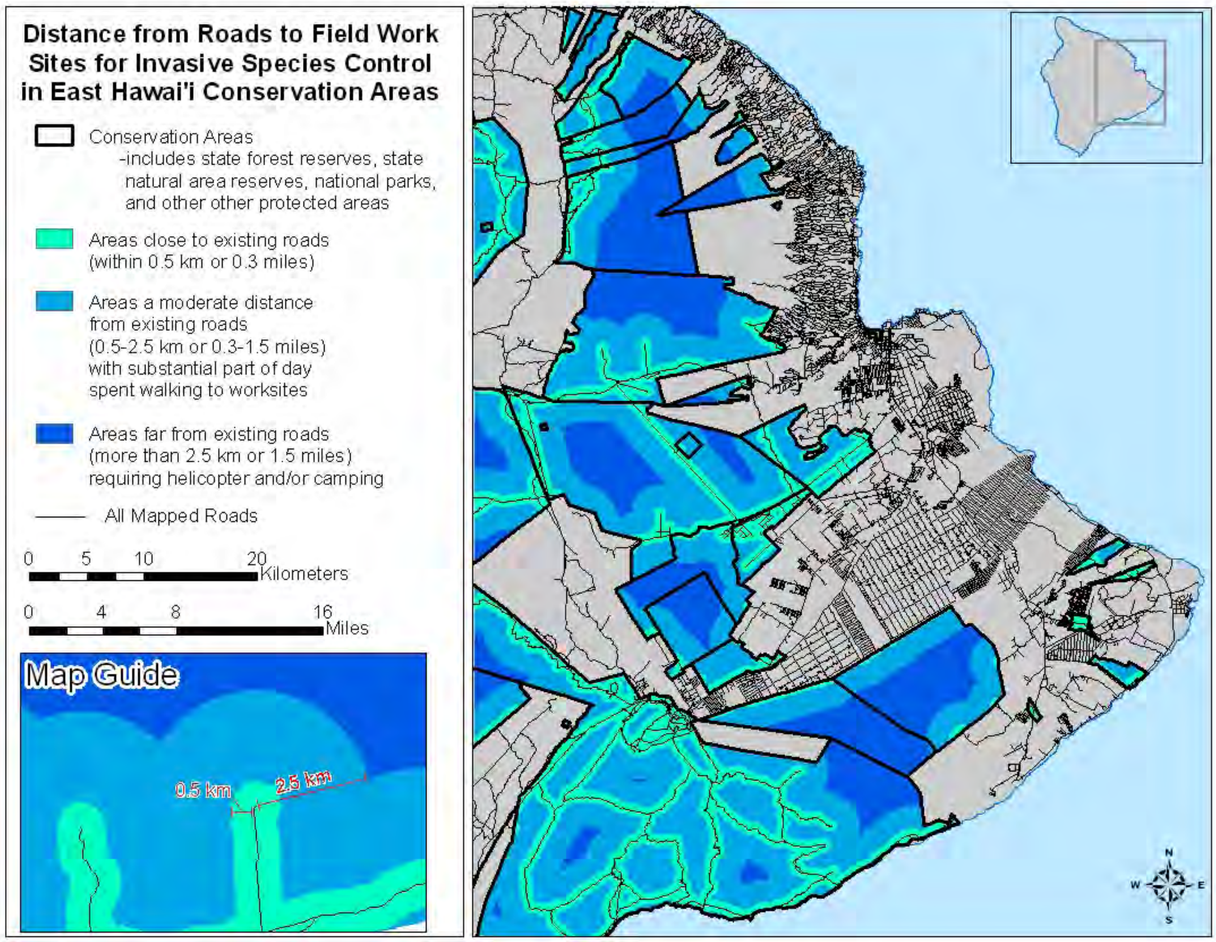
Map 1. Strawberry Guava Habitat across the State. Native Forests and dense infestations of Strawberry Guava were mapped using satellite imagery (from the HIGAP project). The areas either partially or potentially invaded by Strawberry Guava were estimated based on rainfall (areas receiving >1000 mm or 40 inches), elevation (areas below 1,500 m or 5,000 feet and lava flow age (young lava flows excluded).



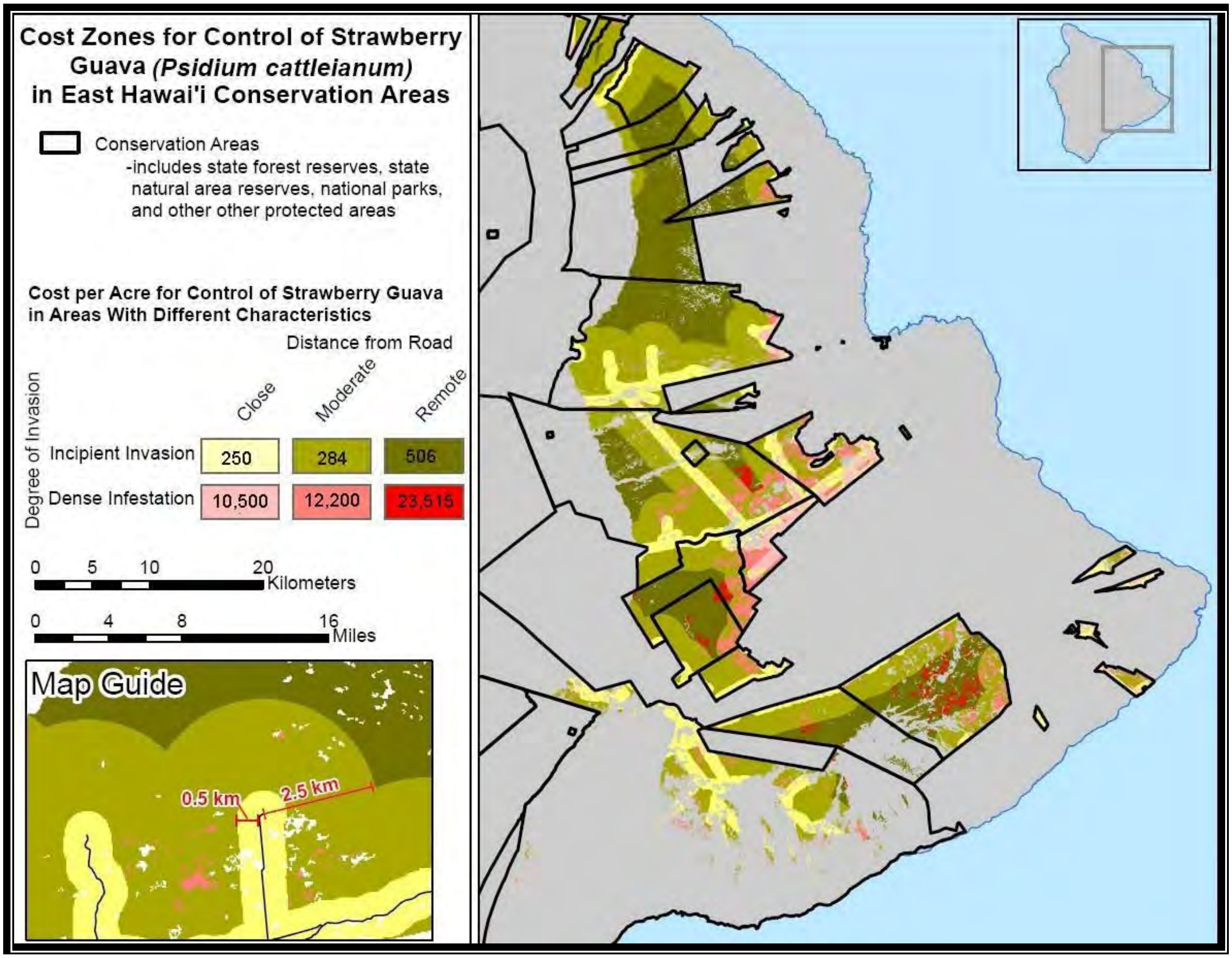
Map 2. Strawberry Guava in East Hawaii Conservation Areas. Dense infestations were mapped using satellite imagery. Recorded locations include extensive fieldwork and indicate areas where the species occurs but was not visible in satellite imagery (these are not the only places the species occurs, but those that have a precise location recorded). The areas either partially or potentially invaded by Strawberry Guava were estimated based on rainfall, elevation and lava flow age.



Map 2. Distance from Roads in East Hawaii Conservation Areas. A Geographic Information System (GIS) was used to calculate the distance from each given location to the nearest road.



Map 3. Cost Zones for Control of Strawberry Guava within East Hawaii Conservation Areas. Control cost is a function of both the severity of infestation and the distance from the nearest road. Costs given in the legend reflect estimates outlined in Tables 1 and 2.



ENVIRONMENTAL ASSESSMENT

Biocontrol of Strawberry Guava by its Natural Control Agent for Preservation of Native Forests in the Hawaiian Islands

APPENDIX 3
Cultural Impact Assessment

RC-0632

Cultural Impact Assessment of the Biocontrol of Strawberry Guava by its Natural Control Agent for Preservation of Native Forests in the Hawaiian Islands

PREPARED BY:

Robert B. Rechtman, Ph.D.,
Frances Kinslow
(USDA Forest Service),
and
Ron Terry, Ph.D.
(Geometrician Associates)

PREPARED FOR:

June 2009

RECHTMAN CONSULTING, LLC
507-A E. Lanikaula St. Hilo, Hawaii 96720
phone: (808) 969-6066 fax: (808) 443-0065
e-mail: bob@rechtmanconsulting.com
ARCHAEOLOGICAL, CULTURAL, AND HISTORICAL STUDIES

Cultural Impact Assessment of the Biocontrol of Strawberry Guava by its Natural Control Agent for Preservation of Native Forests in the Hawaiian Islands

RECHTMAN CONSULTING

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INTRODUCTION

At the request of Ron Terry, Ph.D. of Geometrician Associates, LLC, Rechtman Consulting, LLC with the assistance of Dr. Terry and Frances Kinslow of the U.S. Forest Service, prepared this Cultural Impact Assessment (CIA) for the proposed release of a biocontrol agent (*Tectococcus ovatus*) to combat the spread of the highly invasive strawberry guava (*Psidium cattleianum*) in order to help preserve native forests in Hawaiʻi. Unlike many other projects, which may directly affect only limited areas that can be measured and described systematically, the proposed biocontrol of strawberry guava would eventually affect all areas where strawberry guava occurs in the Hawaiian Islands, particularly locations where it occurs in the wild with some abundance. Figure 1 shows the distribution of strawberry guava around the State of Hawaiʻi. Strawberry guava does not occur on Kahoʻolawe or Niʻihau, but does occur extensively on all other main islands. Strawberry guava, a native of Brazil, was introduced to Hawaiʻi in 1825 as an ornamental fruit tree. In its native Brazil, strawberry guava is kept in check by naturally occurring insect species, including the scale insect *Tectococcus ovatus*. In Hawai'i, without a natural relationship with this insect, strawberry guava grows and spreads quickly, creating thickets where nothing else can survive. This uncontrolled growth is what makes strawberry guava one of the most widespread threats to Hawaiian native forest species (both plant and animal) as well as a potential threat to cultural practices and archaeological sites.

With a roughly 180 year history in the state, strawberry guava is also consumed by many residents, either fresh, or occasionally as juice or in jellies. There are minor economic uses as well, but its economic value is outweighed by the severe impacts it has on native forests, and strawberry guava in the wild is also a host for fruit flies which have a significant negative impact on Hawaiʻi's commercial agriculture. The wood, fruit, and leaves of this species are used for various activities and products, both modern and ancient in origin. In this latter category, the typically hard straight trunk and branches of strawberry guava have been used as a substitute wood in the manufacture of *hula* and *lua* implements when native species cannot be obtained. However, some cultural practitioners feel that substituting an introduced species for the traditionally used native species diminishes the power and essence of the implements. As Sam Gon explains:

> As a conservation biologist, and a Hawaiian cultural practitioner, it breaks my heart to see these dark thickets of strawberry guava crowding out the native trees and plants that should be growing here….Strawberry guava has been in Hawaiʻi so long and is so common in our forests that some people make use of it as a resource. Its wood can be used for *hula* implements and tools, and its fruits are edible. But as a Hawaiian cultural practitioner, I think strawberry guava is a sorry substitute for what we should be using for our implements and tools. We should be using our native trees: *ʻohiʻa*, *alaheʻe*, *lama*, *olopua*, and dozens of other species that are being destroyed by a single foreign species [Strawberry Guava]. (Samuel Gon, transcribed from video interview, 2009)

The current study is intended to accompany an Environmental Assessment (EA) compliant with Chapter 343 HRS. The EA evaluates two alternatives: one of action, the release of a biocontrol agent into the environment; and one of no action, the continuation of currently used control activities, which are limited to chopping and bulldozing (manual or mechanical control) and treatment with herbicides (chemical control). The current CIA assesses the potential cultural impacts from the implementation of each of these alternatives.

This study has been prepared pursuant to Act 50, approved by the Governor on April 26, 2000; and in accordance with the Office of Environmental Quality Control (OEQC) *Guidelines for Assessing Cultural Impact*, adopted by the Environmental Council, State of Hawaiʻi, on November 19, 1997; and was performed in consideration of both federal and state guidelines, among which are the Advisory Council on Historic Preservation's "Guidelines for Consideration of Traditional Cultural Values in Historic Preservation Review" (ACHP 1985); National Register Bulletin 38, "Guidelines for Evaluating and Documenting Traditional Cultural Properties" (Parker and King 1990); the Hawaiʻi State Historic Preservation Statute (Chapter 6E), which affords protection to historic sites, including traditional cultural properties of on-going cultural significance; the criteria, standards, and guidelines currently utilized by the Department of Land and Natural Resources-State Historic Preservation Division (DLNR-SHPD) for the evaluation and documentation of cultural sites (cf. 13§13-275-8; 276-5); and the November 1997 guidelines for cultural impact assessment studies, adopted by the Office of Environmental Quality Control (OEQC).

Below is a description of the alternatives evaluated in the EA, brief natural and cultural historical backgrounds, and the results of consultations with cultural practitioners. Combined, this information provides the context in which to identify potential cultural properties or practices that may be associated with strawberry guava. This is followed by a discussion of potential impacts and suggested appropriate actions and strategies to mitigate any potential impacts.

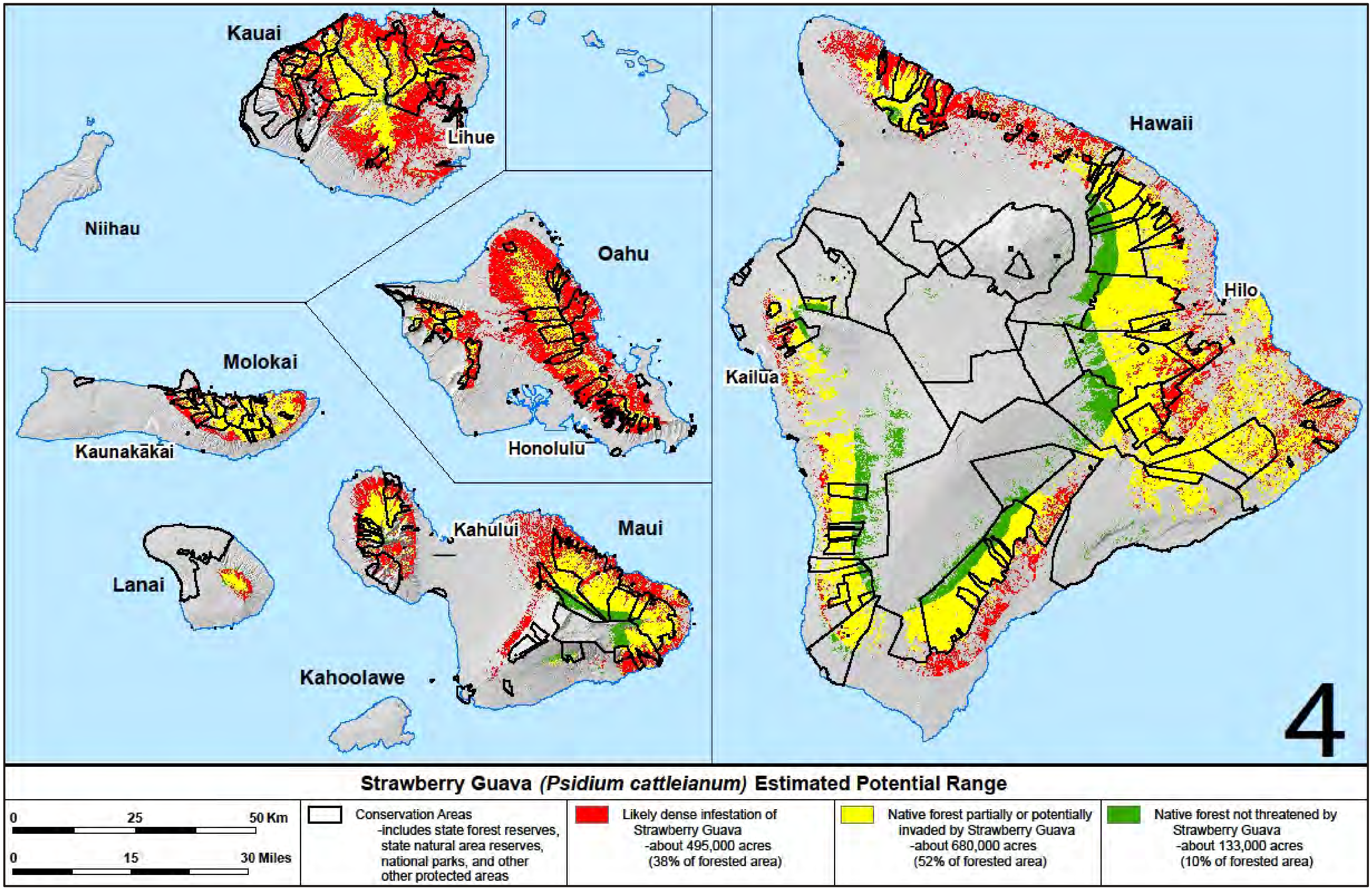

Figure 1. General statewide distribution of strawberry guava.

PROPOSED ENVIRONMENTAL ALTERNATIVES: ACTION AND NO ACTION

Action

Under the action alternative, the scale insect *Tectococcus ovatus* will be released into the environment. The initial release of this biocontrol agent is proposed for the Olaʻa Forest Reserve on the Island of Hawaiʻi (Figure 2). Through natural dispersal and eventual redistribution of the insect by state and federal agencies, it is expected that the range of *Tectococcus ovatus* will extend statewide. This scale insect is expected to only target strawberry guava, and would cause leaf galls that reduce the vigor of the plant and fruiting. Research and testing show that the scale insect is very host specific and will only target strawberry guava. Both in Brazil and in laboratory tests, the scale insect does not move from strawberry guava to other plants such as ʻohiʻa lehua, common guava, and other native and agricultural plants in Hawaii. On strawberry guava, the scale insect will cause leaf galls that do not kill trees but reduce their vigor and fruiting, slowing the growth and the spread of the tree in Hawaii. Expected impacts include a 25-50 percent reduction in vegetative growth rate and 60-90 percent reduction in fruit and seed production, similar to levels seen in its native Brazil. The natural presence of *Tectococcus ovatus* on strawberry guava in Brazil does not reduce the usefulness of either its fruit or wood. The dominant tree of native wet forests in Hawaiʻi, *ʻōhiʻa lehua* (*Metrosideros polymorpha*), has a native, co-evolved insect that similarly produces leaf galls and reduces plant vigor, without impairing the beauty and utility of this tree. The effects of *Tectococcus ovatus* on strawberry guava are expected to occur gradually over a period of decades, providing long-term control, allowing natural substitution of strawberry guava by other plant species, and preventing spread of strawberry guava into areas at risk from invasion. There is however, some uncertainty in how effectively *Tectococcus ovatus* will control strawberry guava in Hawaiʻi. While observations in Brazil and laboratory tests indicate that this agent can significantly impact individual strawberry guava plants, its full effectiveness for protecting remaining Hawaiian forests from the continuous spread of strawberry guava will not be known until after release occurs and post-release monitoring has been conducted.

No Action

Under the no action alternative, the chemical and mechanical control methods currently practiced around the State would continue. While existing methods can effectively control strawberry guava in limited areas, none are effective on the landscape level for slowing the spread of strawberry guava into native forest across large mauka areas. Generally speaking these methods are expensive and can result in significant environmental and cultural impacts as side-effects. The potential non-biological control methods usually include a combination of the use of herbicides, hand and mechanical cutting efforts, and mechanized grubbing. Herbicide and mechanical techniques are being applied in various areas of the Hawaiian Islands, particularly where complete eradication of strawberry guava in limited areas is desired. Successful herbicide or mechanical treatment can be conducted in areas that are small, adjacent to existing roads, and not highly sensitive for reasons of erosion, water resources, or neighbors. However, these treatments are not effective over large tracts, within areas remote from roads, or in certain environmentally and culturally sensitive contexts.

STRAWBERRY GUAVA: NATURAL AND CULTURAL HISTORY

In its native Brazil, strawberry guava is a small tree, 3 to 16 feet tall, rarely growing to 40 feet. Trees growing within forests have slender, twisted stems and small crowns, whereas open-grown trees have dense, spreading crowns (Hodges 1988). Strawberry guava usually occurs as scattered individual trees and rarely in small clumps (Ibid). Flowering occurs mainly in November-December, and fruits mature during February-April (Reitz et al. 1983). Yellow and red-fruited varieties occur, but the former is much more common. The red-fruited variety may be distributed primarily above 2,300-2,700 feet in elevation (Hodges 1988; Vitorino et al. 2000). At upper elevations in its southern range in Brazil, strawberry guava persists in subtropical conditions, experiencing repeated winter frosts. Although not planted commercially on a significant scale, strawberry guava has been cultivated both for its fruit and ornamentally, and is distributed in Brazil beyond its natural range. It is also a popular fuel wood (Hodges 1988).

Figure 2. Location of proposed initial release site at Ola‘a, Hawai‘i Island.

Strawberry guava is common on all the main Hawaiian Islands except Niʻihau and Kahoʻolawe Although strawberry guava is seen wild in areas with annual rainfall as low as 40 inches and can tolerate the low temperatures found up to roughly 5,000 feet in elevation, it is generally concentrated between sea level and 4,000 feet on the windward sides of islands or at cooler and moister elevations in some leeward areas. Although it is found at sea level in coastal areas, it is not highly salt tolerant and is not part of the shoreline flora. It is found scattered in nearly pristine native forests, disturbed native forests, and non-native forests, and also spreads into pasture land and farms. Strawberry guava is not particular as to substrate and it is found in soils of all types, from deep ash to weathered lava to young lava flows. As a result, it is found in many hydrological contexts as well, from areas without streams to highly dissected landscapes, on all types of slopes. Although not classified as a wetland plant, it is reasonably tolerant of short periods of standing water as well. Many casual observers believe that strawberry guava is confined to hedgerows along roads and does not invade the native forest without some pre-existing human disturbance. However, the opposite is true, as it is a very effective invader and is found deep in remote areas. The amount of fruit produced by strawberry guava trees in Hawaiʻi is difficult to estimate, but it is likely to be immense, based on the plant's widespread distribution and the fruit masses it produces in the absence of predators. Humans account for very little of the consumption of the fruits produced. Pigs and rats consume some of this mass, but probably the majority remains on the ground and rots, serving as food for alien fruit flies, including the Oriental fruit fly and Mediterranean fruit fly, which cost taxpayers and farmers millions of dollars annually in quarantine and eradication efforts (Harris et al. 1993; Kaplan 2004; Vargas, Harris, Nishida 1983, Vargas, Nishida, Beardsley 1983; Vargas et al. 1990). Attempts at management of fruit fly pests in Hawai'i are severely constrained by the abundance of fruiting strawberry guava (Vargas and Nishida 1989; Vargas et al. 1995). Although research is ongoing, ornithologists have observed various introduced birds such as Melodious Laughing Thrush (*Garrulax canorus*), Red-billed Leiothrix (*Leiothrix lu tea*), Northern Cardinals (*Cardinalis c ardinalis*), and Japanese White-eyes (*Zosterops j aponicus*) utilizing the fruit; in general, native birds do not consume this fruit, and the prevalence of strawberry guava is one more factor that disadvantages native versus introduced birds in the lowland rainforest (Patrick Hart personal communication to Ron Terry, 2009).

Tectococcus ovatus is entirely specific to strawberry guava and one very closely related plant not found in Hawaiʻi. It does not feed on or otherwise directly affect any animal species. The exclusive relationship between *Tectococcus ovatus* and strawberry guava, which is typical of other gall-forming insects, precludes the insect from shifting to feed on other plant species. Such a shift would require the species to evolve new traits. While the potential for this evolution does exist, given scientific knowledge about evolutionary processes and the life history of related and similar insects, the timeframe for *Tectococcus ovatus* to evolve the ability to use a new host plant would be exceedingly long – many thousands if not millions of years. The likelihood of such evolution is of similar magnitude for hundreds of other insect species already present in Hawaiʻi, which also have evolved close associations with their host organisms over long periods of time.

Strawberry guava was introduced to Hawaiʻi in 1825 for use as an ornamental landscaping plant. As early as 1832, nurseries were selling strawberry guava seeds and trees in Hawaiʻi for this purpose. There is no doubt that during the nineteenth century the fruit produced by these trees was consumed by humans and animals alike. In 1914, the Hawaiʻi Agriculture Experimental Station explored the exportation of strawberry guava as a possible commercial venture, but they found the fruits to be unsatisfactory for storage and shipping. As with common guava (*Psidium guajava*), strawberry guava was eaten raw and used to produce jams and jellies. Anthropologists studying Hawaiian household customs in the early twentieth century include "guava" among examples of food found in a typical household (Green and Beckwith 1928; MacCaughey 1917). As the species was not specified this could have included both *Psidium guajava* and *Psidium cattleianum*. A book published by the University of Hawaiʻi in 1936 encouraged people to use strawberry guava and other commonly available fruits to make up for inadequacies in diet (Miller et al. 1936). The use of strawberry guava as a food source in Hawaiʻi has likely not changed much since the nineteenth and early twentieth centuries. Many residents and visitors to Hawaiʻi can attest to picking and eating fresh strawberry guava fruits right from the tree, and jellies and jams are still produced at the household level. Strawberry guava is often cited as a favorite of children and is noted as a pleasant recollection of childhood for many Hawaiʻi residents.

A mutually beneficial relationship between strawberry guava and feral pigs (*Sus scrofa*) has developed with significant consequences for the proliferation of the former and a potential concomitant increase in the range of the latter. The populations of feral pigs which now roam the forests of Hawaiʻi are descendants of the introduced and more aggressive European boars, which interbred with and eventually displaced the smaller Polynesian pigs. Pigs have since developed mutual relationships with invasive species, whereby pigs forage on the invasive plants, and then carry the seeds to other areas of the forest. In 1976, scientific evaluation of the Kipahulu Valley on Maui (Diong 1982) found an "emergency situation" in which the synergistic movement of strawberry guava and pigs was documented. Pigs dropped seeds into previously uninfested areas, which produced more plants and fruits, in turn attracting more pigs. Although pigs are omnivorous, studies of feral pig diets in Hawaiʻi have found that plant materials make up most of their diet, which is influenced by habitat. Consequently, a pig's diet may be as little as 0%, or as much as 70%, sweet fruits such as papaya, passion fruit, and strawberry guava. The varied diet includes a significant consumption (over 50%) of ferns and grasses, as well as earthworms and carrion for protein (Noguiera et al. 2007).

While it is difficult to quantify the relationship between fruit production and pig populations, the opportunistic nature of the *Sus scrofa* diet would indicate that the most likely result of a reduction in strawberry guava fruits would be for pigs to consume other available foods, and it is unlikely that any significant impact on pig populations would be observed, although localized reductions in populations may occur in some areas. Without discounting the importance of pigs for subsistence in Hawaiʻi, it is important to also consider the well-documented negative impact that pigs have on native species. Pigs are notably destructive to vegetation and the link between pigs and mosquito-borne illnesses that threaten native birds has long been established. From a conservation biology standpoint, the impacts of large feral pig populations on the native forests are considered to be detrimental to the ongoing maintenance of healthy forests, and over decades the land management organizations in Hawai'i have spent hundreds of thousands of dollars on fencing and ungulate removal projects to protect native forest areas. A cultural impact assessment for the 1,264 acre Kapunakea Preserve on Maui concluded that**,** "Strawberry guava…is a weedy tree spreading rapidly in the West Maui Mountains, in part, because of the foraging of feral pigs" (Gon 2008:12).

The Kapunakea cultural study also concluded that, "Strawberry guava forms impenetrable thickets and develops strong root systems that can destroy the integrity of an archaeological site" (Gon 2008:12). Invasive vegetation control is always a concern when considering the long-term preservation of archaeological resources. On a roughly 350 acre section of land owned by Kamehameha Schools in the upland portions of Kahaluʻu Ahupuaʻa in North Kona, strawberry guava was identified as one of the most significant threats to the numerous (roughly 3,500) archaeological features of the remnant agricultural fields documented on their property (Rechtman Consulting 2004). The only techniques currently available for control of invasive vegetation in and around archaeological sites are limited to the use of herbicides and hand-clearing. Mechanized clearing is out of the question as it also results in the destruction of the archaeological features.

It is well documented that the spread of strawberry guava into native forests is devastating to the indigenous flora, having been identified as a threat to the habitat of more than seventy-five federally listed threatened or endangered Hawaiian plant species. This threat also has significant cultural ramifications. The uses of native wet and mesic forest plants in traditional Hawaiian culture, and their appearances in Hawaiian mythology, are extensive (see Kraus 1993); and the trees, flowers, and woods within native forests continue to be extensively used in Hawaiian cultural practices. These native plants represent the physical forms, or *kinolau*, of the ancestral deities called *ʻaumakua*. The upland forests, now some of the last refuges for native Hawaiian plants and animals, are considered *wao akua*, or the regions of the gods. These *wao akua* are sacred and, because of the spread of strawberry guava and other invasive species, are now under serious threat. The loss of these remaining wet forests would be an irrevocable loss to Hawaiian culture. The continuing invasion by strawberry guava will severely impact these traditional resources and associated practices, and eventually may eliminate many of the native plant species. The relationship, however, goes deeper than the use or exploitation of natural resources. Within a Hawaiian perspective, natural and cultural elements, and physical and spiritual realms, are not viewed as separate, but rather parts of an integrated whole. Taking care of the land also helps sustain the culture; and the integrity of the *ahupuaʻa*, the forests and the watersheds from *mauka* to *makai*, is a critical part of this care. It is for this reason that nurturing outposts of at least limited biological integrity, such as the forest area on Hawaiʻi Island referred to as *Wao Kele O Puna*, now in the care of the Office of Hawaiian Affairs, have been so important to Hawaiian cultural practitioners. If *Wao Kele O Puna* and other lowland rainforests of the Hawaiian Islands degrade into a virtual monoculture of strawberry guava, far more than biological diversity will be lost. Chants and *mele* that celebrate the sights, sounds and aromas of the forest will have meanings that can no longer be physically experienced. They will become mere historical accounts of times past, the antithesis of a thriving, living culture.

SUMMARY OF CONSULTATION

As part of the planning process for the potential release of *Tectococcus ovatus* five open-house, information-sharing meetings were held, one meeting each on O‘ahu, Maui, and Kaua‘i; and two meetings on Hawai‘i Island, one in Kona and one in Hilo. Relative to potential cultural issues, public comments fell into two general categories: support for the proposed project on the grounds that the native forests (as cultural resources) need to be restored; and opposition to the proposed project (primarily heard on Kaua‘i) based on the fear that the reduction in strawberry guava will lead to a reduction in feral pig populations and thus have an effect on subsistence activities, namely the hunting of feral pigs. While most Hawaiian cultural specialists would agree that pig hunting was not a traditional cultural practice (see discussion in Burrows et al. 2007), hunting pigs for sport and for subsistence has become a customary practice for many Hawai‘i residents, independent of ethnic background. As Maly and Maly (2004:74) point out based on an extensive review of more than 60,000 native Hawaiian land documents dating between 1846 to 1910, “nearly every reference was in the context of them [pigs] being near-home and as being cared for (raised), not hunted.” While not identified as a cultural practice for the purposes of this study, the potential secondary effects of the release of *Tectococcus ovatus* on pig hunting activities should nonetheless be a socioeconomic consideration within the overall EA.

As an introduced species, strawberry guava is having a devastating effect on native forests and the natural and cultural resources contained therein. Therefore, as part of the current assessment, in addition to the five open-house meetings, it was deemed appropriate to individually consult with native Hawaiian cultural practitioners with connections to Hawai‘i’s forest resources. Dawn Chang of Ku‘iwalu LLC conducted the consultations. While this consultation process was limited in scope and time, it was intended to engage those consulted in a more culturally sensitive small talk story approach. It has been our experience that people, in particular native Hawaiians, tend to be more candid and forthcoming in such a setting. The conversations took place within their community or their office at their convenience. At times there was the sharing of food as a gesture of appreciation. The consultations were conducted with consideration of the following principles: *mākia* or being purposeful, attentive, and respectful of their time; *ha‘aha‘a* or with humility and respectful recognition that individuals have different opinions based upon respective areas of expertise; *hilina‘i* or trust, generally based upon a pre-existing personal relationship or referral by someone they trust; and finally, *kuleana* or responsibility to one another and to our cultural and natural resources. Table 1 lists the individuals consulted.

Table 1 Cultural consultants.

Name	*Association*	*Affiliation*	*Date*
Samuel Gon, III	Cultural practitioner	Nature Conservancy	3/23/09
Lloyd Case	Cultural practitioner/Subsistence hunter	Hawaii Wilderness Assoc.	4/2/09
Leimana DaMate	Cultural practitioner	*‘Aha Ki‘ole* Advisory Comm.	4/2/09
Jonathan Scheuer	Land manager	OHA	4/16/09
Chuck “Doc” Burrows	Cultural practitioner	*‘Ahahui Mālama I Ka Lōkahi*	4/16/09
Kale Gumapac	Cultural practitioner	*Kanaka* Council	3/3/09
Ben Tajon	Cultural practitioner	*Kanaka* Council	3/3/09
Huihui Kanaka‘ole	Cultural practitioner	Edith Kanaka‘ole Foundation	5/5/09

Since its introduction to Hawai‘i roughly 180 years ago, strawberry guava has become known in Hawaiian as *waiawī* (the yellow variety) and *waiawī ula‘ula* (the red variety). None of the consultants identified any traditional cultural practices or belief associated with strawberry guava. While there was some discussion about the use of guava leaves for medicinal purposes it was clearly the *kuawa* (*Psidium guajava*) that was being referred to and not the strawberry guava (*Psidium cattleianum*).

There were some who indicated that cultural practitioners, including *hula* and *lua halau* and woodcrafters, use the strawberry guava wood in the place of harder to acquire native species for the manufacture of certain implements. However, both Sam Gon and Doc Burrows commented that practitioners should be using the native woods rather than introduced woods, and that if strawberry guava is not controlled there will be far fewer native woods available for cultural use.

Lloyd Case and Leimana DaMate also stated that many people on the Big Island burn strawberry guava woods when making smoke meat. Lloyd also expressed concerns as a subsistence pig hunter about the potential adverse impacts to the pig populations that may rely on strawberry guava as a food source.

All of the consultants expressed concerns regarding adverse impacts to native forest resources that will continue to occur as the result of the uncontrolled spread of strawberry guava. Jonathan Scheuer, speaking on behalf of OHA, felt very strongly that if nothing is done now, the native forests in *Wao Kele O Puna* on the Big Island will be destroyed. OHA recently acquired *Wao Kele O Puna* and as cultural steward of the land, has a *kuleana* or responsibility to ensure that the native forests are sustained and available for future generations. The cultural landscape of this and other native forests is a very significant resource which must be protected. While Huihui Kanakaʻole recognized the importance of protecting the native forests from invasive species, she stated that the Edith Kanakaole Foundation opposes the use of biocontrol measures because they find no cultural basis in Hawaiian chants to support such a practice. Sam Gon and Doc Burrows spoke passionately about protecting our native forests from invasive species so that cultural practitioners have resources to gather. Sam spoke about the *ahupua'a* land management concept and how everything is interconnected and interrelated from a Hawaiian cultural perspective. He shared that from his experience there is a visible difference in the water quality of streams in the vicinity of native forests as compared to forests comprised of non-native species. In the former instance the water is clean and clear and in the latter, the water appears dirty and murky.

As for the cultural appropriateness of the use of a biocontrol agent to manage strawberry guava, while all the cultural consultants agree that something needs to be done to protect the native forests to ensure that Hawaiians and others have access to exercise their traditional customary practices, and that the strawberry guava threatens the health of our native forests, there is some debate as to whether biocontrol is the culturally appropriate option. Kale Gumapac and Ben Tajon of *Kanaka* Council expressed concerns that all available options should exhausted before the use of biocontrol to manage the growth of strawberry guava. Huihui Kanakaʻole of the Edith Kanakaʻole Foundation would prefer that the approach focus on getting families to reconnect with the native forests so that they would exercise their *kuleana* to care for the resources. Sam Gon of the Nature Conservancy, Doc Burrow of *ʻAhahui Mālama I Ka Lōkahi*, and Jonathan Scheuer of the Office of Hawaiian Affairs see the problem as very urgent, and they are convinced and feel quite comfortable that biocontrol is an appropriate, measured response and the only effective means of controlling the growth of strawberry guava, which will afford the native forests a chance to recover. Sam Gon noted that while ancient Hawaiians didn't use biocontrol as we know it today, they certainly did use some plants and animals to control others, practicing a concept similar to modern biocontrol. None of the cultural consultants suggested that strawberry guava thickets are a resource that should be saved; rather they expressed their differences on the approach for controlling its spread.

IDENTIFICATION OF CULTURAL RESOURCES, PRACTICES, AND BELIEFS; AND THE IDENTIFICATION AND MITIGATION OF POTENTIAL CULTURAL IMPACTS

The OEQC guidelines identify several possible types of cultural practices and beliefs that are subject to assessment. These include subsistence, commercial, residential, agricultural, access-related, recreational, and religious and spiritual customs. The guidelines also identify the types of potential cultural resources, associated with cultural practices and beliefs that are subject to assessment. Essentially these are natural features of the landscape and historic sites, including traditional cultural properties. A working definition of traditional cultural property is:

> “Traditional cultural property” means any historic property associated with the traditional practices and beliefs of an ethnic community or members of that community for more than fifty years. These traditions shall be founded in an ethnic community’s history and contribute to maintaining the ethnic community’s cultural identity. Traditional associations are those demonstrating a continuity of practice or belief until present or those documented in historical source materials, or both.

The origin of the concept of traditional cultural property is found in National Register Bulletin 38 published by the U.S. Department of Interior-National Park Service. “Traditional” as it is used, implies a time depth of at least 50 years, and a generalized mode of transmission of information from one generation to the next, either orally or by act.

"Cultural" refers to the beliefs, practices, lifeways, and social institutions of a given community. The use of the term "Property" defines this category of resource as an identifiable place. Traditional cultural properties are not intangible, they must have some kind of boundary; and are subject to the same kind of evaluation as any other historic resource, with one very important exception. By definition, the significance of traditional cultural properties should be determined by the communities that value them.

It is however with the definition of "Property" wherein there lies an inherent contradiction, and corresponding difficulty in the process of identification and evaluation of potential Hawaiian traditional cultural properties, because it is precisely the concept of boundaries that runs counter to the traditional Hawaiian belief system. The sacredness of a particular landscape feature is often times cosmologically tied to the rest of the landscape as well as to other features on it. To limit a property to a specifically defined area may actually partition it from what makes it significant in the first place. A further analytical framework for addressing the preservation and protection of customary and traditional native practices specific to Hawaiian communities resulted from the *Ka P a'akai O Ka'āina* v Land Use Commission court case. The court decision established a three-part process relative to evaluating such potential impacts: first, to identify whether any valued cultural, historical, or natural resources are present; and identify the extent to which any traditional and customary native Hawaiian rights are exercised; second, to identify the extent to which those resources and rights will be affected or impaired; and third, specify any mitigation actions to be taken to reasonably protect native Hawaiian rights if they are found to exist.

During the course of this study there were no cultural resources, practices or beliefs identified to be directly associated with strawberry guava. There were no stands of strawberry guava identified as traditional cultural places, and a review of the ethnobotanical literature (i.e., Gutmanis 1976; Handy et al. 1991; Krauss 1993; Neal 1965; Palmer 2003) failed to identify any cultural uses of strawberry guava. There is however a single strawberry guava tree located on the historic Walker Estate that has been placed on Oahu's Exceptional Tree List. Trees are generally added to this list based on significant age and/or size, and owners receive a tax credit for the care of those trees. If this specific tree were to become infected with *Tectococcus ovatus*, it would not lead to mortality, rather it might form leaf galls and inhibit fruiting. If that is considered to be an undesirable result, the effects on *Tectococcus ovatus* on a single tree can be mitigated through the application of any number of widely available horticultural oils.

Conversely, when considering the areas that strawberry guava invades, many would agree that the native forests of all of Hawai'i's islands are part of a general cultural landscape; and thus, from an indigenous perspective and with respect to this study, should be considered a cultural property. The uncontrolled spread of strawberry guava throughout these areas can be seen as a significant cultural impact. Furthermore, strawberry guava has also invaded formerly forested areas that ancient Hawaiians cleared and used for agricultural practices, most significantly on Maui and Hawai'i islands. The threat to the archaeological resources of these areas from the spread of strawberry guava is enormous, both as a result of natural processes and during attempted mechanical control. The no action alternative will lead to continued cultural impacts and provides no mitigative relief for such impacts.

CONCLUSION

It is the conclusion of the current study that the proposed action will have a positive impact and that no action will have a negative impact. The proposed action alternative will serve to enhance valued natural and cultural resources within Hawai'i's forested areas and beyond, and will have no significant adverse impact on any cultural resources, practices or beliefs. The no action alternative has an unmitigated significant negative impact. No action will lead to continued degradation of Hawai'i's valued natural and cultural resources as strawberry guava continues to spread rapidly and overwhelm native forests.

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