CHROMOLAENA ODORATA
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The spread of *Cecidochares connexa* (Tephritidae) in West Africa

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Chromolaena odorata (L.) R.M. King & H. Rob. (Asteraceae: Eupatorieae) is a shrub native to the Americas that has become a problematic invasive in many of the tropical and subtropical regions of the Old World (Holm et al. 1977, Gautier 1992). Two distinct biotypes, that can be separated based on morphological and genetic characters, are recognised within the introduced distribution (Paterson and Zachariades 2013). The southern African (SA) biotype is only present in southern Africa while the Asian/West African (A/WA) biotype is present in much of tropical and subtropical Asia as well as tropical Africa (Zachariades et al. 2013). The first records of the A/WA biotype being naturalised in Asia were in India and Bangladesh in the 1870s but it was only in the 1940s that the first records were made in West Africa when the plant was reported to be present in Nigeria (Ivens 1974; Zachariades et al. 2009). The plant was recorded in Côte d'Ivoire in the 1950s and is now present from the Gambia in the west, across the Congo Basin to Kenya and Tanzania in the east, and northern Angola in the south (Zachariades et al. 2009, 2013).

Cecidochares connexa Macquart (Tephritidae) is a fly which galls the nodes of *C. odorata* and is highly host specific (McFadyen et al. 2003). A strain of the fly that develops on the A/WA biotype of *C. odorata* was collected in Colombia and released in Indonesia in 1995 where it readily established (Zachariades et al. 2009). The fly has now established on all the major islands of Indonesia, in Papua New Guinea, Timor and the Philippines (Day and McFadyen 2012) as well as in India (Bhumannavar and Ramani 2007). Post-release evaluations conducted in Papua New Guinea have indicated that substantial levels of control have been achieved and that crop yield has increased by 50% due to the control of the weed (Day et al. 2013a,b). In Timor Leste the biological control agent has been less successful, possibly due to the prolonged dry period on the island (Day et al. 2013c).

Attempts to rear the fly on the SA biotype have failed (Zachariades et al. 1999) but the success of *C. connexa* in South-East Asia indicates that it may be a good option for control of the A/WA biotype in West Africa. A colony of the fly was sent to Ghana with the intention of release in that country in the 1990s but the colony failed before any releases were made (Zachariades et al. 2009). In 2003 and 2004, releases of *C. connexa* were made in areas surrounding Soubre and Okrouyo in Côte d'Ivoire near the Liberian border (R. Desmier de Chenon, pers. comm. to C. Zachariades, 2009) (Fig. 1). Establishment was successful and the agent was reported to have spread to over 100km from the release sites by 2009 (R. Desmier de Chenon, pers. comm. to C. Zachariades, 2009).

In March 2014, roadside surveys of *C. odorata* in Ghana resulted in the first record of *C. connexa* outside of Côte d'Ivoire in West Africa. Galls on the nodes of *C. odorata* plants were present at 12 sites in Ghana (Fig. 1) and at many of these sites galls were abundant, with very few or no plants that were examined being free of galls. *Cecidochares connexa* emerged from galls that were collected in the field and the identification of the species was confirmed (C. Zachariades pers. comm.). While *C. connexa* was present at all sites where *C. odorata* was present in the western parts of

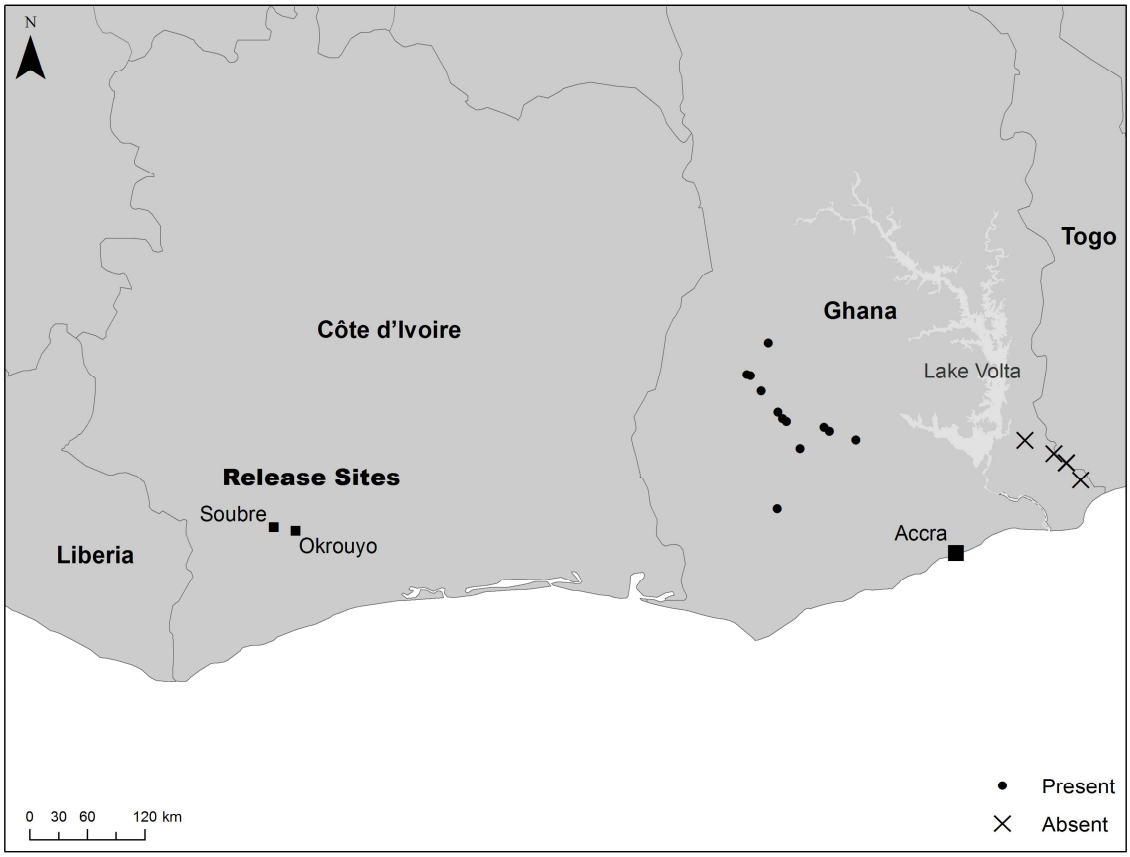

Figure 1. Distribution of *Cecidochares connexa* in Ghana, March 2014. Sites at which *Chromolaena odorata* plants were examined for the presence of *C. connexa* galls are indicated by a ● or x. The region of Côte d'Ivoire in which releases of *C. connexa* were made in 2003-2004 is also shown.

Ghana, no galls were found on plants towards the extreme east of the country, despite *C. odorata* being abundant at four sites (Fig. 1). *Cecidochares connexa* was therefore assumed to be either absent or rare in the eastern parts of the country.

The most likely source of the *C. connexa* population in Ghana was the population established from the releases made in Côte d'Ivoire in 2003/4. This suggests that the biological control agent has spread at least 600km over a ten year period. The absence of *C. connexa* in eastern Ghana could be due to the fact that the insect has not yet spread to that region but it is more likely that its absence is due to the drier climatic conditions in the east of the country. *Cecidochares connexa* is believed to be intolerant of prolonged periods of dry weather (Day *et al*. 2013c). Although the relatively dry eastern region of Ghana may have restricted the spread of *C. connexa* in West Africa, it is also possible that the agent could have crossed this barrier and established in areas of higher rainfall in Togo, Benin and Nigeria. This could have been achieved through long distance dispersal or there could be low density populations across the dry region of eastern Ghana that were not recorded on the survey. Although *C. connexa* had limited success in Timor Leste it did establish (Day *et al*. 2013c) and the average rainfall in Timor Leste is lower than eastern Ghana suggesting that it is possible for *C. connexa* to establish in eastern Ghana. There are however many other factors besides rainfall that should be taken into account when predicting where *C. connexa* is likely to establish.

Surveys for *C. connexa* should be conducted in high rainfall regions of western Nigeria to confirm whether the biological control agent has naturally dispersed into the country. If *C. connexa* is not present in Nigeria then a basic redistribution programme in which galls from western Ghana are sent to high rainfall regions of Nigeria is likely to result in establishment. Given the success of *C. connexa* in Papua New Guinea and the positive implications for agriculture and natural ecosystems in that country (Day *et al*. 2013b), as well as the high densities of the agent in Ghana reported in this article, the redistribution of *C. connexa* throughout climatically suitable areas of West Africa should be considered a priority for *C. odorata* biological control in the region.

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The state of devil weed (*Chromolaena odorata*) in Hawai'i

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Introduction

The infestation of *Chromolaena odorata* R.M. King & H. Rob. (Asteraceae) in Hawai'i was detected nearly four years ago and managers are racing to control this noxious weed before it becomes widespread. *Chromolaena odorata* is commonly known as "devil weed" in Hawai'i, named for the three thick veins in the shape of a pitchfork on its leaves. The O'ahu Army Natural Resource Program and the O'ahu Invasive Species Committee have joined forces to develop and implement management strategies. This article discusses the current and potential impacts of *C. odorata* in Hawai'i, as well as the challenges facing managers in fighting one of the worst weeds in the world.

"We were concerned it was a new island record, but didn't realize how bad it was. The last, worst weed of the Pacific finally reaches Hawai'i." - Scott Heintzman, OANRP crewmember on the initial detection in 2011.

History of Hawai'i

The island state of Hawai'i is the most remote landmass on the planet. Isolated and undiscovered by humans for millions of years, Hawai'i is an evolutionary showcase. Located in the middle of the northern Pacific Ocean, Hawai'i is composed of 137 islands, islets and atolls stretching 2,400km (1,500mi) east to west. Famous for its mild weather, the average year round temperature at sea level is between 22 and 25°C (72 and 78°F). However, with elevations up to 3,960m (13,000ft) and rainfall totals of 25-762cm (10-300in), Hawai'i contains eleven of the world's thirteen climatic zones (Giambelluca et al. 2013).

The extreme geographic isolation and abundance of diverse habitats has given rise to thousands of native species, about half of which are found nowhere else in the world. Over millions of years, new species arrived in the islands only once in every 15,000 to 30,000 years. These few hundred chance colonizers slowly evolved, creating the diverse native flora and fauna of Hawai'i and making it the endemic species capital of the United States (Nature Conservancy 2014).

Undisturbed and uninvaded, unique ecosystems perfected their relationships, performing specific functions that were sustained for 70 million years. This long period of isolation left Hawai'i vulnerable to the activities, disease, and alien plant and animal species brought by humans. In the last 200 years alone, 28 bird species and 97 plant taxa have gone extinct, in addition to 72 taxa of snails and 74 taxa of insects.

Hawai'i has lost more native species to extinction than any other state in the United States (Hawaii Biological Survey 2008).

Invasive species problem in Hawai'i

Not only is Hawai'i known as the endemic species capital of the U.S., it is also infamously known as the "endangered species capital of the world". While the state makes up less than one percent of the nation's land mass, over 25% of the 430 plant and animal species on the US Endangered Species List are endemic to Hawai'i, while many more Hawai'ian species are proposed to be considered threatened or endangered. Invasive species now pose the single greatest threat to the remaining native ecosystems, damaging the environment, economy, and the health and safety of Hawai'i's residents, and poised to push endangered species over the edge to extinction (US Fish & Wildlife Services undated).

There are eight major islands in the easternmost section of the archipelago, upon which 1.4 million people reside. O'ahu is the most populated of these main islands, housing 70% of the state's population. O'ahu is also the most popular tourist destination, hosting an average of 4.5 million visitors from around the world each year (Hawai'i Tourism Authority 2014). More than 90% of all consumer goods are imported from Asia and the Americas, including 85-90% of all food for the state (Leung and Loke 2008). The influx of global travelers and commodities has inundated the islands with an enormous number of alien species to the state. Over 5,000 alien species have become established in Hawai'i in the past 200 years (Hawaii Biological Survey 2009). At this rate, a new species successfully colonizes every 18 days and more continue to arrive every year (USDA Forest Service undated).

The losses of vital environmental services provided by healthy ecosystems and watersheds are only exacerbated by Hawai'i's remote location. The cost of early detection and prevention of invasive species is a fraction of the costs of mitigating their negative impacts. In a study published in 2002, the Nature Conservancy estimated that the economic impact from just three species, viz. miconia (*Miconia calvescens* DC., Melastomataceae), red imported fire ant (*Solenopsis invicta* Buren, Hymenoptera: Formicidae) and the brown tree snake (*Boiga irregularis* (Merrem), Colubridae), could cost Hawai'i $180 million dollars each year (Timmons undated). In addition to the environmental threats, invasive species that can bring disease, sting and bite, reduce water quality and aesthetic values also threaten the state's tourism-based economy by making Hawai'i a less favorable place to vacation and reducing the overall quality of life in the islands (State of Hawai'i Department of Business, Economic Development & Tourism 2011).

Not only do pests reach the islands from international and national sources, but inter-island transport allows invaders to spread across the entire archipelago. County-based Invasive Species Committees (ISCs) emerged in the 1990s as a response to these critical issues. Each of the five main islands in Hawai'i now have a local invasive species committee to address incipient alien species specific to their respective island; Hawai'i County (also known as Big Island): Big Island Invasive Species Committee (BIISC), Maui County: Maui Invasive Species Committee (MISC), Moloka'i island, which is within Maui County: Molokai Invasive Species Committee (MoMISC), Kaua'i County: Kaua'i Invasive Species Committee (KISC) and located on the island of O'ahu is the City and County of Honolulu: O'ahu Invasive Species Committee (OISC).

The O'ahu Invasive Species Committee (OISC) is a partnership of county, state, and federal agencies, private businesses, non-profit organizations and individuals. All are united in cooperative efforts targeting incipient invasive plants and animals that pose the greatest threat to O'ahu's ecosystems, watersheds, economy, public health and quality of life. OISC is a project of the Pacific Cooperative Studies Unit, a conservation and research-based organization operated at the University of Hawai'i at Mānoa.

Threat posed by Chromolaena odorata

Chromolaena odorata was screened using the Hawai'i-Pacific Weed Risk Assessment (HPWRA) and received a score of 28, suggesting that it has the potential to be highly invasive in Hawai'i (Chimera 2009). The Hawai'i-Pacific Weed Risk Assessment is a research project by Curt Daehler (University of Hawai'i) and Julie Denslow (USDA Forest Service) and is supported by funding from the USDA Forest Service and from the Hawai'i Division of Forestry and Wildlife Urban and Community Forestry program. Originally developed in Australia and New Zealand, the assessment is used to evaluate the existing and new imported plants to Hawai'i.

Native to Central and South America, *C. odorata* is a well-documented pest worldwide, including Australia, South Africa, India, the Philippines, Micronesia, Palau, and Guam. *Chromolaena odorata* is drought tolerant and easily thrives in a variety of soil conditions (Witkowski and Wilson 2001). Plants can mature in as little as twelve months producing 800,000 seeds each year for approximately fifteen years. Plants flower during Hawai'i's rainy season, from December-February, and set seed into April. Seeds are easily dispersed by wind, animal and human disturbances and in one study, seeds remained viable for about one year (Witkowski and Wilson 2001).

While *C. odorata* thrives in open, sunny areas, it also can grow in sparse shade and been observed growing beneath ironwood (*Casuarina* sp., Casuarinaceae) stands at Kahuku Training Area (KTA). The plant is adapted to disturbance, such as fire, and dry, dense stands pose a fire hazard. These dense stands also have allelopathic qualities that prevent other plant species from flourishing at the infestation site and may cause allergic reactions in humans and animal (Chimera 2009). If allowed to spread unchecked, *C. odorata* would likely become ubiquitous across dry, mesic-dry, mesic, and even mesic-wet landscapes; it would become a major weed in Hawai'i, furthering stressing native forest remnants.

***Chromolaena odorata* in Hawai'i**

The only known infestations of *C. odorata* in the State of Hawai'i occur on the island of O'ahu. *Chromolaena odorata* was first detected in January 2011 on the north shore region of O'ahu at the Kahuku Training Area. The area is managed by the O'ahu Army Natural Resources Program (OANRP), also a project of the Pacific Cooperative Studies Unit and an

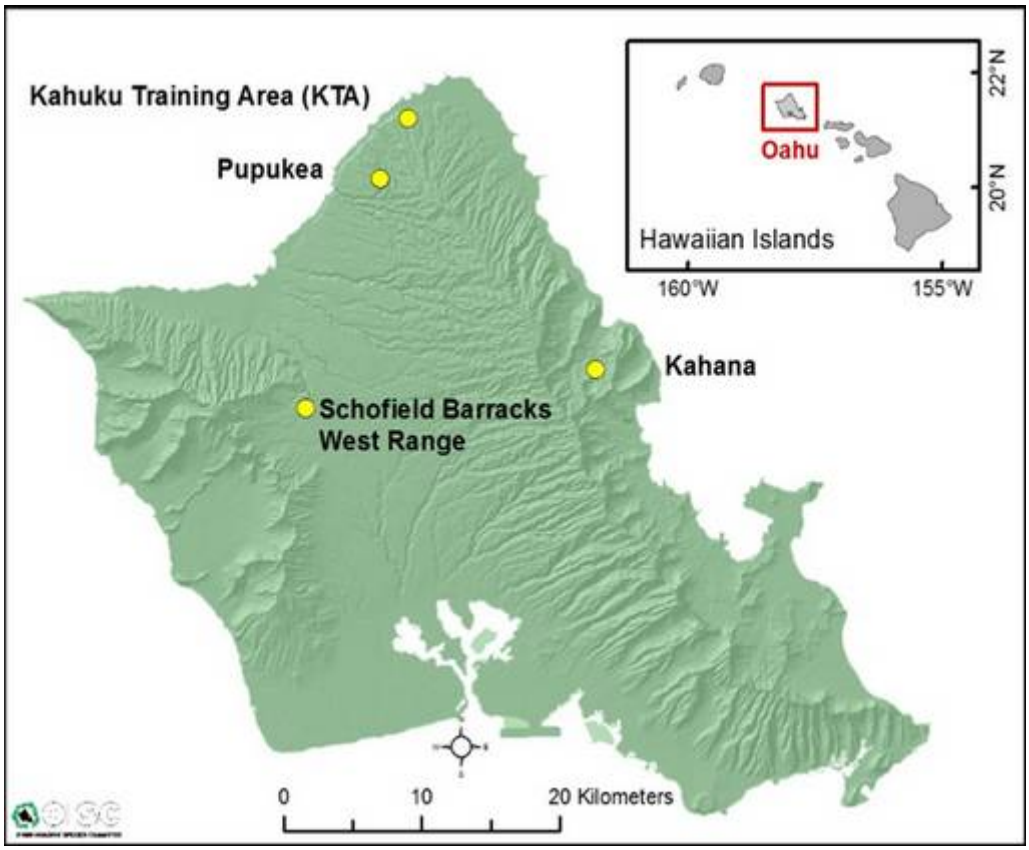

Figure 1. *Chromolaena odorata* treatment and monitoring locations on O'ahu.

OISC partner. OANRP oversees compliance with federal and state conservation laws with the goal to effectively balance the requirements of the United States Army's training mission with its natural resource responsibilities.

The infestation was discovered during routine road surveys specifically designed to detect the presence of incipient invasive species. The crew immediately submitted a specimen to the O'ahu Early Detection Program botanists at the Bishop Museum who not only verified it as *C. odorata*, but that it was indeed the first record of the weed in Hawai'i. It is listed on the State Noxious Weed List and its discovery triggered a rapid response from various agencies.

Chromolaena odorata was likely introduced to Hawai'i at the Kahuku Training Area more than ten years ago via military training activities. Guam is heavily infested with *C. odorata* and is the suspected source for the infestation, although given *C. odorata*'s worldwide distribution, other sources and routes can be hypothesized.

Since its discovery on O'ahu in 2011, there are now four known locations across the island. OISC and OANRP are working together to eradicate *C. odorata* with support from the Hawai'i Department of Agriculture, the O'ahu Early Detection Program and Bishop Museum, Marine Corps Base Hawai'i, the U.S. Fish and Wildlife Service, the Hawai'i Department of Land and Natural Resources, the Hawai'i Invasive Species Council, the Hawai'i Motorsports Association, and other partners.

Kahuku Training Area (KTA) and Pupukea

The Kahuku Training Area (Fig. 1) is approximately 3,800ha (9,400ac) and is located at the northern end of the Ko'olau mountain range, with elevation ranges from near sea level at the coastal plain, rising to 753m (1,860ft) in the uplands. The topography varies from a coastal plain bordered by sheer bluffs, to deep gulches, to the dwindling northern tip of the Ko'olau mountains. The area is bisected by many drainage basins whose slopes range between 3% grade up to 25% or more. The majority of land in KTA had been historically altered through ranching and the cultivation of pineapple and sugarcane. This has resulted in the current vegetation being dominated by introduced species including but not limited to ironwood trees (*Casuarina* sp.), strawberry guava (*Psidium cattleianum* Sabine, Myrtaceae), Brazilian pepper (*Schinus terebinthifolius* Raddi, Anacardiaceae), Guinea grass (*Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs, Poaceae), southern crabgrass (*Digitaria ciliaris* (Retz.) Koeler, Poaceae), allspice (*Pimenta dioica* (L.) Merr., Myrtaceae), shoe button ardisia (*Ardisia elliptica* Thunb., Myrsinaceae), and koa haole (*Leucaena leucocephala* (Lam.) de Wit, Fabaceae). There are seven naturally occurring native communities containing endangered plant species on KTA and OANRP manages these biologically sensitive areas, most of which are located in the mid- to upland areas.

Kahuku Training Area, with parcels owned by both the State of Hawai'i and the USA, is a multi-use property, which poses huge management challenges. KTA is the largest ground-maneuver training area on O'ahu, with various branches of the military utilizing the area to conduct exercises during the week. On the weekends, part of KTA (sub-leased by the State to the Kahuku Motocross Track), opens as the only legal motocross track on O'ahu. These activities compound the spread of *C. odorata* as seeds are easily spread via vehicular

traffic and pedestrian activities, while the plant readily colonizes disturbed soil.

The primary infestation at Kahuku occurs between 30 and 198m (100 and 650ft). The areas of infestation are crisscrossed with motocross trails and heavily used for military training. In 2011, delimiting surveys began and determined that the primary infestation site was roughly 339ha (837ac) containing two high-density hotspots. An outlier, one immature plant, was discovered near an access road in 2011 at the edge of Pupukea Boy Scout Camp (Fig. 1) and the extreme western end of KTA. The most likely vector is recreational activity. The plant was pulled and the location was initially being surveyed quarterly by OANRP, but with no new plants, the area is now surveyed bi-annually.

Delimiting surveys continue to be conducted across KTA. The current size of the primary infestation is 457ha (1,130ac), with outlier sites covering another 7ha (18ac). While the primary infestation area is mostly delimited, the continued discovery of outliers along roads and trails, some of which had already been surveyed, demonstrate the difficulty of keeping control efforts ahead of dispersal. Currently, there are nine outlier locations in KTA, spread across the entire breadth of the training area. Since *C. odorata* was found, annual road surveys have been expanded to include all drivable roads in KTA and in 2014, OANRP began surveying all KTA trails as well.

OANRP conducts ground surveys throughout the year, with the goal of sweeping all known infested sites at least once a year. Hotspots receive focused attention. Over 9,150 plants have been removed since 2011, including 2,500 mature individuals. As part of a contract with OANRP, OISC conducts once-a-month work trips to KTA. Over the course of the four-day camping trip, OISC focuses on the continued ground surveys, monitoring of hotspots, and control of any plants encountered outside of the hotspots, within 200m buffer zones. To date, OISC has controlled 1,934 immature and 688 mature plants. The hotspots are currently scheduled to be treated by OARNP in the future.

Schofield Barracks

Located in central O'ahu, on the eastern slopes of the Waianae mountain range (Fig. 1), Schofield Barracks is exclusively used by the military for live fire and weapons training. The topography includes a flat plain that sweeps up to the west from 200m to 1,220m (660-4,000ft) at Ka'ala, the highest point in the Waianae mountains. To the east, Schofield Barracks is bordered by a large gulch (Kaukonahua) and agricultural lands. The average annual rainfall in the impact area, where all training activities take place, is 101-127cm (40-50in), similar to KTA. The impact area is highly disturbed, with little to no native vegetation, and a long history of fire. It is an open grass- and shrub-land, dominated by *Bidens pilosa* L. (Asteraceae) (beggar's tick) and *M. maximus*, with dense stands of trees clustered in gulches. Most of the infestation is located in the lower reaches of a large gulch, which is dominated by dense *M. maximus*, *S. terebinthifolius* and *Eucalyptus* (Myrtaceae).

Discovered on a routine road survey in May 2013, the Schofield *C. odorata* infestation appears to be much younger than the KTA infestation. It covers 38ha (93ac), and is concentrated in the lower reaches of a grass-dominated gulch, just outside the areas used by troops. The western end of the infestation spills over a major access road. Two outlier sites, totaling less than 2ac, were discovered by Army Cultural Resources staff and reported to OANRP in December 2013 and August 2014. It is suspected that *C. odorata* was unintentionally transported from KTA via training and range maintenance activities, in particular vegetation control and construction around roads and targets. At all sites, ground access is limited by the presence of unexploded ordnance (UXO). Field staff must be accompanied by explosive ordnance experts whenever working off-road; this is an important but restrictive safety precaution. In addition, most of the infestation, particularly both outliers, cannot be accessed while live-fire training is ongoing. OANRP is only able to conduct treatment on select days when the range is closed.

To reduce the potential for further dispersal, OANRP prioritized control of outliers and roadside *C. odorata* patches. These areas are treated every 3-6 months, and are cordoned off to remind range maintenance staff to avoid mowing them. All plants on the west side of the access road are treated every 3-6 months, in hopes of limiting further spread. OANRP plans to spray the eastern portion of the infestation aerially. Annually, all roads within the Schofield training area are driven to look for new *C. odorata* locations. This includes walking around buildings and targets, and even driving through a Radiologically Controlled Area. Fortunately, there are few to no trails at Schofield Barracks.

To date, 530 plants have been removed from Schofield Barracks, including 305 mature individuals.

Ahupua'a O Kahana State Park

Located on the windward side of O'ahu, Ahupua'a O Kahana State Park (Fig. 1) is nestled in a relatively undisturbed valley. The park is about 2,144ha (5,300ac) and ranges in elevation from sea level at Kahana Bay to 813m (2,670ft) at the crest of the Ko'olau mountain range. Kahana is one of the wettest valleys on O'ahu with an average yearly rainfall of 190cm (75in) along the coast, increasing dramatically to 760cm (300in) at the back of the valley. Temperatures can range from 18-29°C (65-85°F). The area encompasses an entire *ahupua'a*, or traditional Hawai'ian land division, which includes lands from the mountains to the sea, and retains significant cultural meaning. Known as a "living park", about thirty families reside in Kahana State Park, sharing Hawai'ian cultural practices and traditions, and assisting with the interpretive programs and restoration efforts. The park is also used for recreational purposes such as hiking, camping and hunting.

Chromolaena odorata was incidentally discovered and reported by a botanist in Kahana State Park in January 2013 about 6m (20ft) off a main trail. OISC conducted the preliminary delimiting survey in May 2013, detecting 25 immature plants in close proximity to the original plant report. Given the location and topography, it is unlikely that the Kahana population occurred via wind-dispersal. It is more likely that recreational activities provided the vector.

The current survey and control area is about 16ha (40ac). OISC also conducts bi-annual surveys across a 24ha (60ac)

area that is adjacent to a priority watershed and has good *C. odorata* habitat. Between May 2013 and August 2014, OISC has controlled 1,663 immature and 36 mature plants at Kahana State Park.

Strategy for control and detection

Control

Both OISC and OANRP utilize similar control measures for *C. odorata*, beginning with setting a 200m buffer around known plants. The buffer zone is then surveyed to delimit the population. If additional plants are found within the 200m buffer zone, then delimiting will continue out another 600m for a total buffer of 800m. All 200m buffer zones around mature and immature plants are surveyed on a regular rotation based on the biology of *C. odorata*. The goal is to sweep all infested areas twice a year (generally in May and October) and to monitor and treat hotspots multiple times a year.

OANRP has had to adjust their strategy at KTA to balance limited resources. Lacking manpower to survey all 800m buffers, and based on staff observations which suggest that trails and roads are the most likely locations for dispersal, OANRP decided to focus ground scours only on 200m buffers around all plants and eschew 800m buffer sweeps for surveys of all roads and trails throughout KTA. These surveys are complemented by intensive sweeps to treat known infested areas, and focused control at hotspots. The densest portion of the infestation is located in a gulch some distance from road access. This core was sprayed aerially once, and future sprays are planned.

Various treatments are being used in the control strategy for *C. odorata*. Seedlings and immature plants can be hand pulled. Small populations and individuals are treated using basal application of triclopyr and larger, woody plants over 2.5 cm (1 in) diameter are treated using the cut-stump method and application of triclopyr. Hotspots are defined by any 10 m radius containing five or more mature plants. These are treated with a foliar application of glyphosate to kill the *C. odorata* and sulfometuron methyl as a pre-emergent to reduce seedling recruitment.

Detection

Lack of funding and resources has prevented early detection surveys in high-risk areas across O'ahu. Incidental sightings during surveys are the current means of early detection outside of known infestation locations. OANRP conducts annual road surveys KTA, Schofield Barracks, and other O'ahu Army training areas between January and March. This involves driving every road and listing all weeds seen, with *C. odorata* as the primary target. Additionally, all trails outside the primary infestation site at KTA are being surveyed to identify any new outlier *C. odorata* sites. Safety concerns regarding UXO at Schofield Barracks prevent surveying trails. Fortunately, there are not many trails on Schofield Barracks, and the few that do exist are not used for training. An aerial survey was conducted at Schofield Barracks to survey the UXO areas and to map the known infestation site.

Outreach

After the initial detection in 2011, the OANRP sent out a pest alert to the invasive species community in Hawai'i via a popular listserv. In particular, the alert was shared with invasive species committees across the State, the Hawai'i Department of Agriculture, the U.S. Fish and Wildlife Service, the College of Tropical Agriculture and Human Resources at the University of Hawai'i Mānoa, a popular local hiking club, and environmental offices at the Marine Corps Base Hawai'i and Army Pohakuloa Training Area on Hawai'i Island. In addition, the discovery was featured in a number of articles in several military newsletters, bulletins and websites. OANRP also created a pest alert poster for *C. odorata*, currently displayed at the Kahuku Motocross track, KTA Range Control office, and Kahana State Park. OANRP staff incorporated *C. odorata* awareness into regularly scheduled briefings of Army Environmental Compliance Officers and Officers-In-Charge. Outreach was also conducted with civilian and contract range maintenance crews at KTA and Schofield Barracks.

OANRP and OISC also conducted outreach at motocross events, handing out flyers and talking with riders about identifying and reporting the weed, as well as decontamination methods for bikes and gear. In the future, both OISC and OANRP would like to conduct more outreach geared towards the recreational audience at KTA and Kahana State Park, encouraging decontamination practices and possibly assisting with the installation of a washrack at KTA for motocross riders.

Ongoing control efforts have removed more than ten thousand *C. odorata* plants. Effective herbicide treatments allow field staff to have confidence that treated plants will die. In particular, areas treated with pre-emergent herbicides appear to have little to limited seedling growth.

Challenges

Numerous challenges have presented themselves in the management strategy for *C. odorata*. Every agency and organization doing invasive species control work in Hawai'i is faced with financial challenges and funding is one of the largest obstacles in the fight against *C. odorata*. It has been difficult to balance *C. odorata* projects with existing invasive species work for both OISC and OANRP.

The infestation locations provide unique challenges for control. At KTA, *C. odorata* continues to spread to previously uninfested areas. The area is highly utilized for military training and motocross. To assist in minimizing spread, a portion of KTA has been temporarily closed to training. However, it is not possible at this time to restrict training activities across the entire infestation area or limit use of the motocross park. Rogue motocross riders leaving the designated track and riding throughout the training area further compound the problem. At Schofield Barracks, access to the infestation site is limited by a busy training schedule and the presence of UXO.

Outreach has also faced challenges as *C. odorata* has a cryptic habit that makes it difficult to identify. Neither OISC nor OANRP have received reports of sightings from the public or outside agencies. It is also difficult to reach a large percentage of all target recreational audiences.

Successes

The partnerships formed between a multitude of agencies and organizations have been able to provide the means for a rapid response and facilitate the current management strategies. New decontamination protocols now require that all military units wash and inspect vehicles before and after conducting activities at KTA. OANRP is conducting a seed trial to gain a better understanding of seed longevity. While there are no final results yet, information on seed longevity will be crucial to define eradication values. This will help develop the most efficient control strategies regarding the frequency of surveys and the value of pre-emergent herbicides. Pest alert posters are present at the entrance to both Kahana State Park and the Kahuku Motocross Track. Kahana State Park staff have also been extremely cooperative in assisting with access permits for OISC to conduct surveys in the park.

Needs and future plans

The *C. odorata* infestation on O'ahu is fairly new, and while it is too early to identify trends, OISC and OANRP are working together to create annual adaptive management plans to best utilize their combined resources. Biocontrol agents for *C. odorata* have been released in Micronesia and Guam, which are heavily infested with the plant. Guam is seeing positive results with the release of two biocontrol agents; a moth, *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Erebidae), whose larvae defoliate the plant and a stem-galling fly, *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) (Reddy et al. 2013). Of the two insects, *C. connexa* is showing the most efficacy as a biocontrol agent due to its resistance to insect-induced plant defenses and advanced mobility capabilities (Reddy et al. 2013). The infestation on O'ahu is still relatively small and it is unknown at this time whether biocontrol methods will be implemented, but new and innovative management strategies continue to be discussed and tested through the partnerships on O'ahu. One of OISC's main mission objectives is to educate and involve the public to help stop the spread of invasive species, and it is working on a social-media based marketing campaign to raise awareness among the recreational audiences at KTA and Kahana.

The need for a comprehensive biosecurity program at all harbors and ports for international and inter-island commerce and travel is an essential component for invasive species prevention. Community engagement and legislative support will be necessary to promote, install and enforce biosecurity protocols for the State of Hawai'i. Invasive species issues in Hawai'i have been highlighted in local and national media outlets, in part due to the recent detections of little fire ant (*Wasmannia auropunctata* (Roger), Hymenoptera: Formicidae) and coconut rhinoceros beetle (*Oryctes rhinoceros* (L.), Coleoptera: Scarabaeideae) on O'ahu in December 2013. Media coverage of the extensive damage and power outages caused by fallen invasive albizia (*Albizia falcataria* (L.) Fosberg, Fabacaeae) trees on Hawai'i Island during Tropical Storm Iselle in August 2014 is also raising general awareness about the impacts invasive species have throughout the state.

The O'ahu Army Natural Resources Program and O'ahu Invasive Species Committee are dedicated to containing and fighting the infestation and will continue to work on all fronts with the hope of eradicating *C. odorata* from Hawai'i.

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Changes afoot in the IOBC Global *Chromolaena odorata* Working Group

Costas Zachariades, the convenor of the working group since 2007, recently stepped down and handed over the reins to Michael Day, Senior Entomologist at Biosecurity Queensland: Department of Agriculture, Fisheries & Forestry, Brisbane, Australia (Anonymous 2014). The Working Group has decided to expand its focus slightly and take the new name Biological Control and Management of Eupatorieae Weeds. The argument for including all Eupatorieae is that there are active biocontrol projects against numerous species in several countries. These include *C. odorata*, *Mikania micrantha*, *Ageratina adenophora*, *A. riparia* and *Campuloclinium macrocephalum*. Furthermore, there are similar agents on *C. odorata* and the two *Ageratina* species, and these weeds have similar habits. In addition, there are good agents on all these weeds — but these have not been widely released globally. So there is a good case to tackle all these weeds at the same time under a Working Group, rather than trying to target one agent on one weed in one country. Expanding would certainly increase the participation and interest across regions (Anonymous 2014).

The website for this Working Group will be maintained at the Agricultural Research Council in South Africa for the time being, although it will be revised and made more accessible (see below for current website address).

It has not been decided whether to expand the focus of this Newsletter to include other Eupatorieae yet. Please contact Michael Day at Michael.Day@daff.qld.gov.au if you would like to contribute an article on *C. odorata* or another species of Eupatorieae.

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About this newsletter…

- The *Chromolaena odorata* Newsletter is published at irregular intervals. To contribute articles pertaining to biological control and management of *C. odorata* and other Eupatorieae weeds, please contact Michael Day, Biosecurity Queensland: Department of Agriculture, Fisheries & Forestry, GPO Box 267, Brisbane, Qld 4001, Australia. E-mail: Michael.Day@daff.qld.gov.au
- This newsletter is produced at the Agricultural Research Council (ARC), South Africa, in association with the *Chromolaena odorata* Working Group of the International Organization of Biological Control (IOBC).
- Trade names of products are used to simplify the information. No endorsement of named products is intended.
- Any opinion, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the ARC or the IOBC.

For information on the biological control of *Chromolaena odorata*, please visit the website of the IOBC Working Group on this weed, hosted by the ARC, at http://www.arc.agric.za/arc-ppri/Pages/Weeds%20Research/Chromolaena/Chromolaena-odorata.aspx

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