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Technical Report 166

Prevention, early detection and containment of invasive, non-native plants in the Hawaiian Islands: current efforts and needs.

A report based on a symposium and workshop held at the 2008 Hawaii Conservation Conference in Honolulu

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Introduction

Invasive, non-native plants (or environmental weeds) have long been recognized as a major threat to the native biodiversity of oceanic islands (Cronk & Fuller, 1995; Denslow, 2003). Globally, several hundred non-native plant species have been reported to have major impacts on natural areas on oceanic islands (Kueffer *et al.*, 2009). In Hawaii, at least some 50 non-native plant species reach dominance in natural areas (Kueffer *et al.*, 2009) and many of them are known to impact ecosystem processes or biodiversity. One example is the invasive Australian tree fern (*Cyathea cooperi*), which has been shown to be very efficient at utilizing soil nitrogen and can grow six times as rapidly in height, maintain four times more fronds, and produce significantly more fertile fronds per month than the native Hawaiian endemic tree ferns, *Cibotium* spp. (Durand & Goldstein, 2001a, b). Additionally, while native tree ferns provide an ideal substrate for epiphytic growth of many understory ferns and flowering plants, the Australian tree fern has the effect of impoverishing the understory and failing to support an abundance of native epiphytes (Medeiros & Loope, 1993). Other notorious examples of invasive plant species problematic for biodiversity and ecosystem processes in Hawaii include miconia (*Miconia calvescens),* strawberry guava *(Psidium cattleianum),* albizia *(Falcataria moluccana)*, firetree (*Morella faya*), clidemia (*Clidemia hirta*), kahili ginger (*Hedychium gardnerianum*), and fountain grass (*Pennisetum setaceum*), to name just a few. Fireweed (*Senecio madagascariensis*) is a recent example of a seriously problematic invasive species for Hawaii's agriculture and is damaging certain high-elevations native ecosystems as well.

The threat of invasive plants has long been recognized in Hawaii and is well documented (e.g. Cox, 1999; Loope & Kraus, 2009 in press; Loope *et al.*, 2004; Mooney & Drake, 1986; Stone & Scott, 1985; Stone *et al.*, 1992). In many respects, Hawaii may be near the forefront among national and international efforts to address the burgeoning threat of invasive plants, perhaps especially in the field of outreach and education (Holt, 1996; Van Driesche & Van Driesche, 2000). However, given the scale of the problem many challenges still need to be addressed and gaps in the existing management system need to be identified. In particular, it appears that new non-native plant species are still introduced to the Hawaiian Islands at a high rate with little or no regard for their potential invasiveness. In fact, a Pacific-wide and a global survey of non-native plants on oceanic islands have both shown that on Hawaii among all archipelagos by far the highest number of problematic invasive species known from other areas in the world is already present (Denslow et al. 2009, Kueffer et al. 2009). Hawaii lacks an effective mechanism for tracking what species are present or incoming. For instance, early detection nursery surveys conducted on Maui in 2008 found over 300 species of cultivated vascular plants that have not previously been recorded in Hawaii (Starr *et al*., in prep.). In spite of an innovative Hawaii Biological Survey (e.g. Eldredge & Evenhuis, 2003), there is no mechanism for recording presence of a species until it becomes naturalized.

Some of these new introductions may quickly become serious pests. Fireweed, first recorded in Hawaii on the Big Island in the early 1980s, is now considered one of the worst weeds of pastures and is also invading natural areas from near sea level to above 10,000 feet. Although the cultivated and as yet non-invasive *Cortaderia selloana* has been present in Hawaii for 50 years or more, the morphologically similar *Cortaderia jubata* was simultaneously found to be present on Maui and invading on a large scale in 1989. It played an important role in inspiring the establishment of the Maui Invasive Species Committee (MISC) in 1997, and MISC now spends roughly $200,000 per year removing and containing *C. jubata* to keep it from becoming widespread in high-elevation conservation lands of East and West Maui.

The existence of many similar examples shows that to date regulatory action to prevent new invasive plant species from establishing and spreading in Hawaii has not yet been as successful as it needs to be. In particular, because some problematic invasive species known from other areas in the world (Kueffer *et al.*, 2009; Weber, 2003) have not yet been recorded from Hawaii, preventive measures against the introduction and spread of such likely invasive species is therefore an urgent need for Hawaii. Indeed, regulation of importation and early detection and eradication of introduced species before they become abundant and widespread are widely considered the most cost-efficient and often only effective measures against the threat of new invasive species (Kueffer & Hirsch Hadorn, 2008; Wittenberg & Cock, 2001).

Timing seems favorable for Hawaii to achieve effective protection against the threat of new invasive species through prevention, early detection, and eradication/containment. Through the establishment and evolution of Invasive Species Committees (ISCs) on each major Hawaiian island, the institutional capacity has been built up for prevention, early detection, containment, and outreach at an island scale. Weed risk assessment (Daehler *et al.*, 2004) and early detection methodologies (Starr *et al.*, in review-a, b) have been developed and tested specifically for Hawaii. Containment strategies have been successful (e.g., Special Ecological Areas in Hawaii Volcanoes National Park), and so have eradications of particular species on an island scale (e.g. mullein (*Verbascum thapsus*) and other species on Maui, fireweed (*Senecio madagascariensis*) on Kauai). These successful management strategies may be further strengthened through recently developed novel approaches in research (e.g. remote sensing, species distribution modelling, and molecular genetics tools). Another major recent achievement is the gained support of the plant industry for preventive measures against invasive species (see p. 13ff). Last but not least, regulatory action is also moving forward. Passage of House Bill 2517 by the 2008 Hawaii House and Senate and prompt signing of the bill into law by the Governor provides hope that action to ban the sale of a meaningful suite of restricted weeds can quickly proceed through the rulemaking phase into the implementation phase.

This report documents these achievements and experiences and provides a range of perspectives on how to further develop prevention, early detection and containment of invasive species in Hawaii. The report is based on a symposium and workshop held at the 2008 Hawaii Conservation Conference in Honolulu on 31 July 2008.

Synthesis by the editors

This report presents a snapshot of a development in progress. It includes both summaries of current achievements and processes and tools in place (paragraphs "Current invasive, non-native plant categorization efforts" and "Toolbox") and a number of opinions on future perspectives ("Perspectives"). We highlight in this section some of the main current issues for an effective biosecurity system against invasive plant species in the Hawaiian Islands.

Challenges and opportunities for biosecurity in Hawaii

A particular challenge for biosecurity in Hawaii stems from the small land area combined with the highly complex topographic landscape. A species newly introduced to an island may within a short period of time be dispersed to a broad variety of habitats representing most world climates from wet tropical to cool alpine climates. The topography also makes many areas very difficult to access so that eradication is almost impossible through mechanical or chemical control once a species has established in a remote area. Therefore biosecurity in Hawaii must be particularly effective in stopping the introduction and early spread of new potentially problematic, non-invasive plants.

A major opportunity for biosecurity in Hawaii arises by each island's isolation from the others, providing a natural form of containment of species that are introduced only to one or some of the islands. However, containment between islands is only effective if transport of plant material or other vectors, both deliberate and accidental, is effectively controlled between islands. Also, reports of new plants have to be shared among islands and agencies in a fast and effective way (e.g., through a common and standardized early detection database for all Hawaiian Islands).

Voluntary measures and legal regulation of environmental weeds

An evolving view is that government (i.e. Hawaii Department of Agriculture [HDOA]) regulation and government/community action (coordinated through Invasive Species Committees) combined with public understanding and industry support seems a promising approach to getting traction on Hawaii's invasive plant issue.

An example of a promising voluntary scheme of industry support is the gained support of the plant industry for preventive measures against invasive species (see p. 13ff). Monitoring will be important to document the effectiveness of the scheme.

However, regulatory action is needed to complement voluntary schemes. A necessary 100% compliance to control very problematic invasive, non-native species in all management stages from prevention to eradication and containment can only be achieved through establishment and enforcement of laws and rules. For instance, on Maui the Maui Invasive Species Committee (MISC) removed nine of 10 known populations of *Cryptostegia grandiflora* successfully, but was not able to access the last population on private land. The species may spread again from the remaining population and negate the whole effort. The biosecurity systems of New Zealand and Australia provide successful examples of strict legal regulation that may serve as potential models adaptable to the specific context of Hawaii (see "Perspectives"). Passage of House Bill 2517 by the 2008 Hawaii state legislature and prompt signing of the bill into law by the Governor provides hope that action to ban the sale of a meaningful suite of restricted weeds can quickly proceed through the rulemaking phase into the implementation phase. A quick implementation of the law including a comprehensive list of potentially problematic species (see Appendix) will be a relevant step towards a more comprehensive legal biosecurity system for the Hawaiian Islands.

Prioritization of environmental weeds for different management action

The experiences of the ISCs show that on a local scale, a differentiated and flexible prioritization system is needed that allows for different priority categories and for flexible adaptation of listing with management experiences (e.g., stop an eradication effort if it proves not feasible). The New Zealand system provides a possible model for implementing such a differentiated system in a legal framework (see p. 21ff). Criteria for prioritization may differ for banning entry, sale, or ownership, regulating intra- and inter-island movement, seeking eradication, or pursuing ongoing control and containment.

The Hawaii-Pacific Weed Risk Assessment (HP-WRA) (Daehler *et al.*, 2004; www.hpwra.org) provides a valuable tool that has been tested successfully with some buy-in from the landscape industry, but it has been used to date mostly to evaluate species already in Hawaii. We suggest that the HP-WRA be applied to all species included in the Weber (2003) and Kueffer *et al.* (2009) databases. It may be expected that most if not all species in those databases will be rated as high weed risk by HP-WRA, providing an excellent source for populating Hawaii's restricted list with species not already in use by Hawaii's green industry. If a species is already in use by the industry in Hawaii, the industry may be involved in deciding whether to continue using it or whether it should be discontinued and placed on the Hawaii Department of Agriculture's restricted list.

Need for better documentation of impacts of Hawaii's invasive plant species

There is a need for a system that compiles evidence on impacts of environmental weeds in Hawaii among experts and practitioners. Impacts of invasive species depend on the habitat and management context (Kueffer & Daehler, 2009) and observation from other areas may not always be transferable to Hawaii. For instance, the impact of *Falcataria moluccan*a on soil properties differs markedly between stands established on very nitrogen-poor soils in Hawaii (Hughes & Denslow, 2005) and stands on very phosphorus-poor soils in the Seychelles (Indian Ocean) (Kueffer *et al.*, 2008). Or monotypic stands of a non-native tree may hinder native plant regeneration in Hawaii (Mascaro *et al.*, 2008) yet non-native tree species have been shown at times to promote native plant regeneration in other locations (Kueffer *et al.*, 2007; Lugo, 2004). Evidence from Hawaii on impacts of particular non-native species is therefore needed to prioritize management action (e.g., biological control) against already established non-native plants.

The Hawaii Exotic Plant Evaluation Protocol (HEPEP) is an existing attempt to compile published and unpublished evidences on impacts of invasive plants in Hawaii (p. 10ff). However, HEPEP is currently not funded. The IFAS assessment of the impacts of non-native plants in Florida's natural areas,[1] and the use of a systematic review methodology by the UK Centre for Evidence-Based Conservation[2] are established methodologies that could be applied in Hawaii to compile and validate information on impacts of invasive plants.

Remote sensing seems to have much promise for determining and demonstrating impacts of environmental weeds (see p. 36). For instance, using airborne imaging spectroscopy, Asner and Vitousek (2005) were able to determine how biological invasion altered the chemistry of forest canopies. The nitrogen-fixing tree *Myrica faya* doubled canopy nitrogen concentrations and water content as it replaced native forest across a Hawaiian montane rain forest landscape. They also demonstrated that the understory herb, *Hedychium gardnerianum*, reduced nitrogen concentrations in the forest overstory and substantially increased aboveground water content.

Early detection

Early detection work is in place on all islands, but there is a need for a comprehensive database of all non-native plant species present in Hawaii to assist early detection. Such a database should be built starting with existing sources and databases (see p. 28ff). Also, it

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[1] http://plants.ifas.ufl.edu/assessment/

[2] www.cebc.bangor.ac.uk/

is of paramount importance that all plants for sale are accurately labeled. This would help tremendously for early detection efforts, and should become compulsory for importers and sellers of plants (see p. 17).

The number and magnitude of introductions of a non-native species can greatly increase the probability that the species becomes invasive (Reaser *et al.*, 2008); among other possible causes, multiple introductions may in some instances provide new genetic resources necessary for adaptation to novel environments (see p. 39). Thus prevention and early detection efforts should also be directed towards preventing secondary introductions of already introduced species.

Eradication and containment

Prevention and early detection should be the priority action to prevent plant invasions. However, recent experiences in Hawaii show that effective eradication and containment can work. For instance, fireweed (*Senecio madagascariensis*) has been successfully eradicated from Kauai, and the same is true for Malabar melastome (*Melastoma candidum*), parkinsonia (*Parkinsonia aculeata*), downy rose myrtle (*Rhodomyrtus tomentosa*), Himalayan raspberry (*Rubus ellipticus*), mullein (*Verbascum thapsus*), and other invasive plant species on Maui. The Special Ecological Area (SEA) approach that focuses on excluding invasive plants from designated areas has proven to be a successful containment strategy in the Hawaii Volcanoes National Park on the Big Island (see p. 33ff). A continuous control effort has been needed to keep invasive plants out of SEAs, but management costs have decreased markedly after initial weeding and management; since the start of the program the National Park has considerably increased the managed area of SEAs.

Current categorization efforts for invasive, non-native plant in the Hawaiian Islands

The Hawaii-Pacific Weed Risk Assessment (HP-WRA) and the Hawaii Exotic Plant Evaluation Protocol (HEPEP)

Based on presentation by Curt Daehler and inputs from Charles Chimera

The weed risk assessment system for Hawaii and the Pacific Islands (HP-WRA[3]) is a science-based system to assess the risks posed by non-native plants in Hawaii. It is derived from a system developed for and used in Australia.[4] The HP-WRA uses four assessment categories:

- H (HP-WRA) – High risk (not necessarily currently known to be invasive in Hawaii)
- H (Hawaii) – Serious impacts in Hawaii documented by two or more published sources
- L (HP-WRA) – Low risk (not 'zero risk')
- L (Hawaii) – Low risk (widely planted > 50 years with no signs of naturalization)

To date (as of 28 April 2009), 806 species have been assessed by the HP-WRA, of which 278 plants have been rated as "high risk." It takes 1-2 working days for a full assessment of a species with the HP-WRA.

An issue with the HP-WRA is that it uses only evidence from published sources (including non-peer reviewed references from the internet). The Hawaii Exotic Plant Evaluation Protocol (HEPEP[5]) is an attempt to compile unpublished evidence (e.g. from

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[3] www.botany.hawaii.edu/faculty/daehler/wra

[4] www.daff.gov.au/ba/reviews/weeds/system

[5] www.botany.hawaii.edu/faculty/daehler/WRA/hepep.htm

invasive species and natural area managers, or hikers) on impacts of invasive species that are already established in Hawaii, and it integrates field observations from Hawaii with the HP-WRA. To date, 69 alien plant species introduced to Hawaii and rated as "high risk" by the HP-WRA have been further evaluated with the HEPEP, with 43 species subsequently categorized as "documented invasive." Public release of these findings is pending review by a HEPEP committee. The maintenance of the HEPEP protocol is not currently funded.

Prioritization of non-native, invasive plants by the Invasive Species Committees (ISCs)

Based on presentations and round table by Lori Buchanan, Keren Gundersen, Julie Leialoha, Rachel Neville & Teya Penniman

In 1991, agencies and individuals on the island of Maui formed an interagency working group, the Melastome Action Committee, to combat invasion of the weed tree *Miconia calvescens*, which threatened Maui's watersheds and biodiversity. Funding from state and county sources to address the threat of miconia on Maui began in 1994-95. In 1997, this group decided to expand its scope and formed the Maui Invasive Species Committee (MISC), whose purpose was to eradicate or contain incipient populations of potential high-impact invasive species before they spread as far as miconia had. MISC partners included a variety of federal, state, county and private entities. MISC developed a plan in 1998 that established categories (exclusion, eradication, containment, large-scale management) and set priorities and responsibilities for pest management. In 1999-2000, an action plan that focused on eradication and containment of invasive plants was launched to employ a crew for combating top-priority species. The plan was funded by $700,000 raised from federal, state, county, and private sources.

MISC's efforts inspired similar coalitions to be formed on other islands. Currently, there are Invasive Species Committees on the Big Island (BIISC), Oahu (OISC), Molokai (MoMISC), and Kauai (KISC). These committees serve as successful models of local cooperation to address aspects of the invasive-species threat in Hawaii. The ISCs have been successful at implementing some level of rapid-response protection within Hawaii by reducing many populations of an array of invasive species, mostly plants. The efforts to date cannot be viewed as comprehensive because of the large standing crop of incipient invasive species in Hawaii and the continual arrival of new invasions, but the ISCs have made a good start at developing and implementing meaningful action plans.

The ISC website[6] elaborates on current targets and initiatives of each of Hawaii's ISCs. From their beginnings, the ISCs have emphasized local education and outreach, including effort at invasive species prevention and early detection.

The ISCs have a shared process involving an annual priority-setting workshop, committee/board meetings every 2-3 months, and additional meetings as needed to focus on high priority species or issues. All the ISCs engage in a statewide process involving participation in meetings of Hawaii's Coordinating Group on Alien Pest Species (CGAPS)[7], involvement in legislative issues related to invasive species, and national and international interactions/consultation. Each ISC has, to some extent, its own approach to prioritization of invasive, non-native plants for different management actions; this is probably not surprising given the substantial difference among islands in size, funding, ISC partners, urbanization etc. Though there are good reasons for the ISCs to move toward standardization of approaches and datasets, the flexible nature of the ISCs is likely to continue, given the unique situation on each island.

As one example of committee-selected targets for containment/eradication as well as other foci for outreach by particular ISCS the Kauai Invasive Species Committee (KISC) presented at the workshop a scheme with five categories for addressing non-native, invasive plants:

- *Early detection species*. These species are (in order of priority): i. known to be on Kauai, but limited in distribution; ii. already present on neighbor islands, but not known to be on Kauai; iii. invasive elsewhere in Pacific, but not known to be on Kauai; iv. invasive elsewhere in the world, but not known to be on Kauai.
- *Active target species*. These species are deemed "eradicable." All known infestations are treated and thereafter monitored. After successful control an active target species is included on the list of early detection species. Examples on Kauai: long thorn kiawe (*Prosopis juliflora*), fireweed (*Senecio madagascariensis*).
- *Containment species*. These species are possibly beyond eradication but worth containing to a limited area. Example on Kauai: fountain grass (*Pennisetum setaceum*).
- *Community awareness species.* These species are only locally naturalized but are not currently targets for eradication. They have, however, been assigned to Category A (do not plant) by the plant industry (see next page) because of their invasiveness. Example on Kauai: fiddlewood (*Citarexylum spinosum*).
- *Management area control / eradication species*. These species can be locally controlled or eradicated in high-value watershed or natural areas. For some species control efforts are underway by conservation groups other than the KISC.

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[6] www.hawaiiinvasivespecies.org/iscs/

[7] www.hawaiiinvasivespecies.org/cgaps/

Examples on Kauai: Australian tree fern (*Cyathea cooperi*), kahili ginger (*Hedychium gardnerianum*), and strawberry guava (*Psidium cattleianum*).

As another example of an ISC approach, the Maui Invasive Species Committee (MISC) pioneered early detection in the late 1990s in collaboration with U.S. Geological Survey (USGS). MISC primary targets were chosen in 1997, but MISC has since added numerous species to its “eradication” target list based on roadside surveys (Loope *et al.*, 2004; Starr *et al.*, in review-a, b). Species have been prioritized for eradication or containment based on the following criteria:

- Level of risk/threat/potential impact (high risk to natural areas if containment not achieved)
- Limited distribution and perceived likelihood that known distribution closely approximates actual distribution
- Feasibility and ease of control (cost, tools, seed bank)

Originally, the primary purpose of early detection (road) surveys was to identify high-risk targets that were not yet widespread, comprising "low-hanging fruit" for eradication or at least containment. In practice, actual decisions as to whether to adopt particular species as targets have been based on each potential target having advocates present the merits of the case for eradication and the MISC “board” of experienced individuals reviewing evidence to ideally reach a consensus decision based on the above criteria. More recently, early detection on Maui has included “nursery surveys” to find potential invaders at the earliest stages, ideally before they have been widely sold or otherwise distributed and to identify targets for outreach and for future road surveys.

Preventive measures by the plant industry

Based on the presentations by Christy Martin, Chris Dacus, and Boyd Ready

Over the past decade, there has been growing recognition of the need for involving the plant industry in efforts against invasive plant species. An international workshop at Missouri Botanical Garden in 2001 consolidated early efforts at collaboration among diverse interests and produced guidelines in the so-called “St. Louis Declaration on Invasive Plant Species” (Baskin, 2002). In 2002, CGAPS started an outreach program to involve Hawaii’s plant industry in preventive measures against the local invasive plant threat. In 2005, a voluntary agreement involving the “Codes of Conduct” was launched. The signatories of the Codes of Conduct pledged to: i. have new plant introductions screened for their potential to be invasive in Hawaii (using the HPWRA); ii. work with natural resource/conservation groups to identify some incipient (not widespread) invasive plants and agree to discontinue use/sale of these plants wherever possible; and iii. identify non-invasive alternatives and help promote the use of non-invasives.

In 2005 the Hawaii Chapter of the American Society of Landscape Architects (HASLA)[8] launched an anti-invasive-species initiative to increase the support of preventive measures in the plant industry. A "lesson learned" was that if the plant industry had been involved in the development process that led to the HP-WRA, industry knowledge and valuation of the industry could have productively helped to shape the final product and obtain more rapid buy-in. In the HASLA process the following stakeholders were involved: landscape architects, nurserymen, arborists, horticulturists, agronomists, construction contractors, maintenance contractors, and federal, state, and city employees from Oahu, Maui, the Big Island, and Kauai. One of the main objectives of the HASLA was to complement the HP-WRA risk assessment with a broader cost-benefit assessment. The committee reviewed 168 alien plants that scored high in the HP-WRA risk assessment, of which 31 were known to be invasive in Hawaii. The initial assessment allowed for six possible determinations: a. do not plant, b. continue to plant, c. plant but refrain from using near sensitive environments, d. obtain industry input and consensus, e. do not plant if equal alternative is propagated, f. request additional information. After the initial review and follow-up consultation, 134 of the 168 plants were assigned to Category A (do not plant), and 34 to Category C (plant but refrain from using near sensitive environments). The HASLA process is still ongoing. In addition to other options, the process is currently investigating whether the New Zealand National Pest Plant Accord (NPPA)[9] – a cooperative agreement between the nursery and garden industry association, regional councils, and government departments with biosecurity responsibilities – can function as a model for Hawaii.

In 2007 and 2008, both HASLA and CGAPS conducted surveys to determine the level of commitment to preventive measures in the plant industry. Generally, the plant industry proved to be very committed to the prevention of invasive plants and a need for more guidance and regulations was formulated. For instance, 2/3 of the respondents supported a mandatory risk screening of all new plant imports using HP-WRA.

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[8] www.hawaiiasla.org/

[9] www.biosecurity.govt.nz/nppa

Perspectives

How do invasive plants arrive in the Hawaiian Islands?

A change in attitudes toward purposeful introductions is needed in the public sector worldwide to abandon promotion of introductions that have turned out in many cases to be highly invasive (e.g. Cook & Dias, 2006; Richardson, 1998; Ruiz, 2003). In Hawaii, many of the early forestry introductions were for the intended purpose of watershed improvement (Woodcock, 2003). *Falcataria moluccana* is a dramatic example of a tree promoted by government agencies in Hawaii and the Pacific islands for forestry until very recently and that has now become viewed as one of the most damaging invasive species (Hughes & Denslow, 2005). Other major pathways of early post-European contact, introductions of non-native plants included garden plants and species for pasture improvement (Daehler, 2005). *Neonotonia (Glycine) wightii* is a relatively recent example for Hawaii of a "pasture improvement" species that has invasive qualities.

Today deliberate introduction by humans is still the pathway by which most non-native plant species currently reach the United States (Mack & Erneberg, 2002; Reichard, 1997), including the Hawaiian islands (Staples & Herbst, 2005; Yee & Gagné, 1992). The "horticulture" pathway is complex, involving: botanical gardens and arboreta, nurseries, seed trade among garden clubs and horticultural societies, the seed trade industry, trade in medicinal and culinary herbs, aquaria, and government and private efforts to prevent erosion, among other sources (Reichard & White, 2001). Yee & Gagné (1992) found that in Hawaii professional and non-professional collectors may be responsible for more non-native plant introductions than commercial enterprises and that botanical gardens have been most responsible for large-scale plant introductions. They reported that of over 8,000 species said to be cultivated in Hawaii (as of the late-1980s), only about 15% are commonly or occasionally cultivated. Many botanical gardens had exchange programs with other gardens to increase their collections and had programs for propagation and distribution for "the most promising plants" – a mechanism through which commercial nurseries obtain plants (Yee & Gagné, 1992). Internet sales of plants and seeds have burgeoned over the past decade with almost no regulation, while personal botanical exploration has become more of a factor with increased travel to far-flung destinations.

Deliberate introductions have proven particularly problematic on oceanic islands. While among all naturalized non-native plants (including weeds of highly disturbed sites) deliberate introductions make up some 50% of the species, some 90% of problematic invaders of natural areas are deliberate and only some 10% are accidental introductions (Kueffer et al. 2009).

Nevertheless, invasive plants establish in Hawaii by means other than by plant lovers and the green industry. Wester (1992) concluded that about 42% of 810 non-native flowering plant species known to be naturalized by 1986 (based on published records and specimens at Bishop Museum) had arrived accidentally. "Accidental" introductions (e.g., on contaminated equipment) are rarely actually documented, but it is well known that *Senecio madagascariensis* has been repeatedly introduced to various Hawaiian islands as a contaminant in grass seed spread along road banks (Herbst *et al.*, 2004; Lorence *et al.*, 1995).

A possible future introduction pathway may establish through the biofuel industry (see symposium "Biofuels – panacea or pandora's box?" held at the 2008 Hawaii Conservation Conference)[10]. Chinese tallow (*Triadica sebiferum*), a highly invasive tree species in southeastern U.S., is not on any prohibited list for Hawaii. It is on Bishop Museum's checklist of cultivated species but there is not as yet any record of naturalization. Some in Hawaii have expressed concern that this species should be placed on the restricted list in fear that someone would try to introduce this species to Hawaii for biodiesel fuel production (see e.g. Low & Booth, 2007).

[10] www.hawaiiconservation.org/2008hcc_schedule.asp

Hawaii needs cohesive, comprehensive quarantine / biosecurity legislation

By Philip Thomas

Introduction

Quarantine/biosecurity legislation in Hawaii regarding harmful and/or non-native species needs to be cohesive, coherent, and comprehensive. Such regulation should encompass all organism types, and is dependent upon accurate identification of organisms entering, present in, and leaving the state. Regulation needs to address species entering or leaving the state; sale of species in the state; inter-island transport of species within the state; and cultivation/possession of regulated species. A consistent and fair mechanism to address exceptions should be put in place.

With respect to potentially invasive species, regulation should include lists of both permitted and prohibited species. Organisms which are on neither list should be considered "new" to the state. "New" organisms should be prohibited until appropriate risk assessments are done, at which time the organism may be listed as either permitted or prohibited.

Although some of the suggestions herein might already be covered by existing legislation and/or rules, Hawaii's current legislation and rules are piecemeal, ineffective (because they are not comprehensive), and inconsistent (e.g., by default, animals are excluded from importation without a permit, but plants are allowed).

Compulsory identification of organisms

A prerequisite to any effective quarantine/biosecurity system is identification of all organisms to species level. The onus should be on the importer/exporter/transporter/seller to correctly identify every organism that is imported, exported, transported, or sold within the state.

Permitted and prohibited species approach

The State of Hawaii should consider implementing an approach similar to that of Western Australia and perhaps elsewhere that utilizes three sets of lists of species: a list of permitted species, a list of prohibited species, and by default a(n implicit) list of new organisms (those organisms not explicitly included on either of the other lists). The list of permitted species would include species whose import, transport, export, sale, and/or possession is allowed. The list of permitted species may include species whose import/etc. may (or may not) be restricted in some way, i.e., within the constraints of specified conditions; however, conditions should be specified for each species. A list of prohibited species should be maintained of those species whose import, transport, export, sale, and/or possession is explicitly banned. Other organisms, those not explicitly covered by either or the other lists, would be considered "new" to the state. An organism would then be considered "new" if it is just discovered to exist in the state, or if it is proposed for import and not yet known to be present in Hawaii. All organisms, whether known to be present in the state or not, should be considered "new" by default until each is assessed and added to the appropriate list (permitted or prohibited). A key point is that any "new" organism should be prohibited from import, transport, export, and sale (and possibly possession) until each is assessed. The necessity of the seemingly conservative slant of this point is because of the unique nature of biological risk.

The case of biological invasions is a special case among risks because – due to the unique nature of biological risk – the consequences of failure to avert undesirable biological introductions can be profoundly devastating, irreversible, and permanent. One must assume that (a) anything brought into the state can/will escape and fulfill its worst potential; and (b) additional genetic material, even of species already present, poses additional risk.

Areas of regulation

There are four areas of regulation of organisms that need to be addressed: importation (at the state border); sale; possession/cultivation/movement of the species within the state; and export.

Organisms should not be allowed to enter the state except under the provisions for that species in the state's list of permitted species. Alternatively, the species could be accepted based on a rapid assessment of the risks that the state would incur upon that species' entry (see below).

Provisions for inspection of incoming biological materials must be included. Additionally, since not all shipments can be physically inspected, consistent and effective inspection may provide an even more important deterrent: the knowledge by importers that there is a very real chance of being caught (for deliberate or accidental violations), so adequate compliance measures will more likely be taken.

Meaningful restrictions on inter-island movement of plants and animals must be created and enforced in order to prevent spread of invasive/pestiferous species from infested to uninfested islands. Restrictions should include prohibition of cultivation of certain species. In some cases, for example, when eradication is being attempted via an active control program by an invasive species committee, landowners should be compelled to comply with removal of a species from their property, which could include allowing access to the property for work by an authorized agency. (People to whom this raises concerns about "property rights" should consider the rights of others to not suffer consequences of foreseeable harm [e.g., plant invasions] from activities [e.g., harboring invasive plants] that occur on others' properties.)

Restricting sale of invasive species reduces/removes incentive for propagation/ perpetuation of the species for sale. Disallowing export of certain species will help reduce incentives for propagation/perpetuation of these species.

Risk assessments

An assessment of the risk of invasiveness posed by each species proposed for import (or considered for other regulation) should be carried out by the State. An assessment ideally should be requested before an organism is brought to the state border (and certainly before selling/distributing/exporting them).

Assessments can be either "rapid" or "full." Western Australia has implemented rapid assessments for plants entering that state by having trained personnel to do a literature survey across a wide-ranging set of references to determine whether a species has caused problems elsewhere in the world. Entry of a species can be prohibited based on this rapid assessment. Rapid assessment results can be challenged; if challenged, a more thorough evaluation can be done.

If such a system were implemented in Hawaii, the quick assessments could be provided by the State at no charge to the importer as a service to businesses. If denial of entry is the result of a rapid assessment, the cost of a full assessment could be fully or partially borne by the importer.

Exceptions

Exceptions to any set of rules will inevitably be requested, so a mechanism needs to be in place to consistently and fairly handle exceptions. The process of exception handling should explicitly acknowledge that the long-term costs of biological introductions are not typically borne by those who stand to benefit from the introductions in the short term, and that some potential damages are irreversible (e.g., impacts on native ecosystems).

Enforcement

Penalties for noncompliance should be meaningful (so misidentifications cannot simply be absorbed as a normal cost of doing business), since the social cost of noncompliance is potentially extremely high and will almost certainly not be borne by the importer.

Strategy for requesting a new system

As for the strategy for getting this (or any system) in place, ask for what is best. If what is best is attempted to be compromised in the legislative process, you will at least have a logical basis to argue against changes. If you ask for less than what you know is best, you will almost undoubtedly get a suboptimal solution; don't cripple yourself from the start by asking for a compromised system. After major changes to regulations are made, it will likely be a long time (decades?) before the issues are revisited by the legislature. Legislators may assume that "the issue has been taken care of" and will not want to re-address the issue soon.

I caution against getting caught up in trying to fit specific requests into the existing framework. Instead, I propose consideration of a completely new paradigm: instead of couching changes in terms of our current patchwork legislation and rules, perhaps the entirety of our quarantine/biodiversity regulations needs to be overhauled to allow the opportunity to "start over" with logically cohesive content.

For successful discussion of this proposed system, I believe that it will be critical to separate the definition of this system from other, predictably contentious issues. In particular, the determination of which organisms, if any, that are already present in Hawaii to "grandfather" (allow as exceptions to parts of the new legislation) should be kept as a completely separate issue from the definition of the system to be implemented in the future. The issue of "grandfathering" is likely to be contentious, so it particularly needs to be decided upon separately from the issue of a general regulatory system to deal with biosecurity/quarantine in the future. Additionally, specific ways to handle other proposed exceptions should be a separate issue than the defining the basic system. Attempts to incorporate these things before establishing a logically consistent system will likely result in a less cohesive--and less effective--biosecurity system.

New Zealand's approach to invasive species means identifying risks and mitigating them, supported by strong legislation

Provided by Chris Buddenhagen

Overview

New Zealand's Biosecurity Act of 1993 guides pest management in New Zealand. Its two main purposes are 1) to prevent new pests generally and identified "unwanted organisms" specifically, through border control surveillance and 2) to manage pests already established in the country. The Act draws together a number of key government agencies at the national and regional levels, with roles identified in the Act or outlined subsequently in interagency agreements. The Act is empowers or gives powers and functions to authorities to define, prevent and manage pests, pest agents, and unwanted organisms.

A major outcome is that goods and species are not allowed to be imported into the country without a risk assessment. Legal introductions of new organisms and hazardous substances are considered by the Environmental Risk Management Authority and are accepted or declined based on analysis of risks, costs and benefits. A commodity cannot be imported without an Import Health Standard, which determines the conditions under which the commodity can be imported safely; specific problems/risks and concomitant mitigation measures are identified. Compliance is enforced on a cost recovery basis, and border protection officers can destroy or refuse shipments that contain any pest, not just specific pests. They may also treat commodities to destroy pests and charge the importer, since the general rule is that pests should not be introduced with commodities.

Regional management of pest species already present is usually species led, and is implemented through "Regional Pest Management Strategies" that are written via a public consultation process and signed off by regional governments and councils. Local "Biosecurity Officers" typically enforce regional pest management strategies. Land managers such as the Department of Conservation or Regional Authorities are also implementing standardized approaches to identify high priority sites for protection in terms of biodiversity values. At such sites all invasive species that threaten key values may be controlled to low levels. Typically success is measured in terms of reaching specific levels of the invasive species target, and or by recovery in the biodiversity values.

Introduction

New Zealand's approach to invasive species management was greatly modified in the early 1990s at about the same time that the Resource Management Act (RMA) of 1991 was being put in place. This Act determined how New Zealand's environment should be managed. The RMA (1991) and the Biosecurity Act (1993) (BA) provide guidelines and process for the implementation of plans and decision-making by local, regional and national government bodies. All agencies and individuals, especially landowners and land managers, are potentially subject to National and Regional Pest Management Strategies requirements implemented under the BA (1993). The BA (1993) legislation is an empowering piece of legislation.[11]

Generally, "the environment" is considered to be the thing that is protected in the Act. It includes:

a. Ecosystems and their constituent parts, including people and their communities;
b. All natural and physical resources;
c. Amenity values; and
d. The aesthetic, cultural, economic, and social conditions that affect or are affected by any matter referred to in paragraphs (a) to (c) of this definition.

The Environmental Risk Management Authority (ERMA) is in charge of managing risks associated with legal introductions of new organisms, genetically modified organisms and pesticides under the Hazardous Substances and New Organisms Act (1996). All of the acts take into consideration Maori values, as defined by the Treaty of Waitangi.

Legislation in New Zealand is usually proposed by officials and written by lawyers, political science majors or other graduates who work for each member of parliament, or in Government Departments. When bills are proposed there is a process for public submissions while select committees consider a given bill or amendment; all proposed amendments would be reviewed by staff involved in the development of the overall bill or amendment. The culture of government in New Zealand is pragmatic and earnest, mixed with a fair amount of typical politics, but grandstanding is a bit frowned upon culturally.

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[11] www.legislation.govt.nz/act/public/1993/0095/latest/whole.html#DLM315250

Biosecurity New Zealand

At the national level, Biosecurity New Zealand, a division of the Ministry of Agriculture and Forestry (MAF), manages pre-border, border and post-border biosecurity including seeds and nursery stock, for species that are already in New Zealand or may arrive accidentally. It also does management of nationally important pests, as well some oversight of the Regional Pest Management Strategies. Commodities are managed via Import Health Standards; all imported goods considered to pose a risk are required to have a standard and importers must comply with the standards of treatment, and inspection therein.

Import Health Standards

Import Health Standards are put in place for the import of risk items into New Zealand that pose a biosecurity threat. These standards include the requirements that must be undertaken in the exporting country, during transit and during importation, before biosecurity clearance can be given. The standards exist in order to mitigate the risks associated with bringing items into New Zealand.

Cost recovery

All cargo inspections and treatments at the border are done on a full cost recovery basis. Cargo is assessed in terms of risk; not all cargo is inspected.

Hazardous Substances and New Organisms Act (HSNO) (1996) and the Environmental Risk Management Authority (ERMA)

ERMA consists of an Authority and an Agency[12]. The agency is in charge of managing risks associated with legal introductions of new organisms, genetically modified organisms, and pesticides. The overall mission of the Authority of ERMA New Zealand is to “achieve effective prevention or management of risks to the environment, public health and safety associated with importing or manufacturing hazardous substances and introducing new organisms, and their use."

This mission, achieved principally through actions by the quasi-judicial Authority and the Agency of ERMA New Zealand, is to:

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[12] www.ermanz.govt.nz

- achieve cost-efficient and effective decisions on applications under the HSNO Act which take appropriate account of benefits and costs as well as risks, to New Zealand;
- promote compliance with the Act and with the Authority's decisions;
- promote public understanding and knowledge of risks associated with new organisms and hazardous substances and how to prevent or manage them, and
- enhance the HSNO Act as an effective legislative framework for the prevention or management of HSNO risks.

While the purpose of the HSNO Act is to protect human and community health and safety, and the environment, the intention of the Authority is to pursue that purpose in a way that recognizes that there are benefits as well as risks associated with new organisms and hazardous substances. ERMA uses risk management principles outlined in a publicly available document to guide its work. If an organism's introduction would pose too much of a threat to the economy, environment or other values, it will not be allowed.

Regional Pest Management Strategies

Regional strategies allow local councils, cities or regional authorities to define pests and management goals for them through a public consultation process. There is a requirement that pests and management actions proposed for inclusion in the strategy should provide more benefits than costs. Once a strategy is approved, council's or other authorities can charge or use property taxes to fund implementation of the strategy, but for some pests, control is required to be done by landowners; with failure to comply, officials or contractors are hired, control is done and the bill is sent to the landowner.

Additionally, the BA (1993) provides certain powers to officials working to implement an approved strategy or to respond to a new incursion. Powers include authority to cease importation of organisms, do control, use substances and record information.

Unwanted Organisms Register

An "unwanted organism" is defined in the Biosecurity Act 1993 as any organism a chief technical officer believes capable of causing unwanted harm to any natural and physical resources or human health. Chief technical officers for biosecurity come from a number of government departments. "Unwanted organism" also includes any new organism the Environmental Risk Management Authority (ERMA) has declined approval to import, or any organism specified in the Second Schedule of the Hazardous Substances and New Organisms Act 1996.

While MAF, or another department, has no obligation to act against an unwanted organism simply because it has that status, MAF must be satisfied that goods or organisms given biosecurity clearance show no signs of harboring unwanted organisms.

National Pest Plant Accord

The National Pest Plant Accord (the Accord) is a cooperative agreement between the Nursery and Garden Industry Association, regional councils and government departments with biosecurity responsibilities (primarily the Ministry of Agriculture and Forestry and the Department of Conservation). All pest plants listed under the Accord have been declared unwanted organisms under the Biosecurity Act 1993. This declaration prevents their sale, propagation or distribution across the country. Regional councils undertake surveillance to prevent the commercial sale and/or distribution of these plants.

Notifiable Organisms

A “notifiable organism” is any organism which has been declared as such by an “Order in Council.” The Biosecurity Act requires every person to report an organisms' presence to a chief technical officer if the person:

- suspects an organism that is a notifiable organism is present in any place in New Zealand;
- believes that it is not established in that place; and
- believes that a chief technical officer is not aware of its presence.

All notifiable organisms are unwanted organisms, and are generally limited to those organisms that cause serious harm to natural and physical resources or human health.

Regional Pest Management Strategy (RPMS) Process, Requirements and Powers

The following summarizes the pertinent steps in the process and the main requirements for an RPMS, as specified by the Biosecurity Act:

1) Define your “pest”

- any organism can be specified as a pest

2) Decide what action to take

- do everything vs do nothing!
    - Total Control
    - Containment
    - Surveillance

3) Decide how to fund

- direct rating vs actual charges
    - general rate
    - targeted rate
    - landowner/occupier

A) Regional council responsibility

- requirement to consult
- benefits must outweigh costs

B) RPMS process development

- Proposed RPMS
- Final RPMS
- Right of appeal for submitters (Environment Court)

C) RPMS cost/benefit

- Regional council responsibility
    - benefits must outweigh costs
- Section 72:
    - cost/benefit
    - economic
    - ecological
    - soil, water quality
    - human health
    - Maori

D) Biosecurity Act Powers

- S. 106 Power to require assistance
- S. 109 Power of inspection
- S. 113 Power to record information
- S. 114 General powers

- S. 119 Power to seize abandoned goods
- S. 120 Power to intercept baggage, etc.
- S. 121 Power to examine organisms
- S. 121(A) Power to apply article or substance to place

Other invasive species management

Land managers such as the Department of Conservation or Regional Authorities are also implementing standardized approaches to identify high-priority sites in terms of biodiversity values for protection. At such sites all invasive species that threaten key values may be controlled to low levels. Typically, success is measured in terms of reaching specific levels of the invasive species target, or by measuring detectable recovery in the biodiversity values that they are trying to protect. Sometimes rules of thumb are applied where a study identifies that a certain index level of a pest will result in recovery of the biodiversity values of interest, in which case the goal is to control to that level. The Department of Conservation manages 30% of New Zealand's land area and mainly engages in the control of invasive species at high-value sites. It engages in control of pests over large scales and eradications of animal and plant pests on offshore islands or within high values sites. All government agencies must conform to any Regional Pest Management Strategy in much the same way as a private landowner would.

Note: This summary of the way things work in New Zealand is based on my limited understanding gained during the first few years of implementation of these laws. I have not worked in New Zealand since 2001.

Toolbox for prevention, early detection and containment

Data sources for non-native plant species present in the Hawaiian Islands

An immediate difficulty in addressing plant invasions in Hawaii is a far from complete knowledge of what non-native plant species are here, and hence what potentially invasive plant species are here. New information arises continually. The updated Manual of Flowering Plants of Hawaii (Wagner *et al.*, 1999) is inevitably incomplete, although updates can be accessed online.[13] There has not been a systematic effort by the Hawaii Biological Survey or anyone else to document island by island distribution of the plant species in cultivation until they become naturalized. A valuable recent compilation is a Bishop Museum website[14] (Imada *et al.*, 2006) with documentation for about 10,000 plant taxa cultivated in gardens of Hawaii. Intriguingly, many of these taxa, while not yet documented as naturalized, are known to be invasive plants elsewhere in the world. This effort was compiled as a spinoff of the project to produce the book, “A Tropical Garden Flora: Plants Cultivated in the Hawaiian Islands and Other Tropical Places” (Staples & Herbst, 2005). The list was originally compiled mainly from lists supplied by major botanical gardens and makes no claim of completeness. Verification of 60-70% of the species has been accomplished through collection of voucher specimens for the Museum collection and through the complex effort of verifying nomenclature. In the "Methods" section, the authors state: “One source of names currently unavailable due to privacy considerations is the invoices accompanying shipments of plants introduced to the Hawaiian Islands from outside the USA. It is unknown how many new species of plants arrive in Hawaii annually via horticultural introductions for commercial nurseries and landscaping. Because of this unavailability, this checklist will never be totally complete or up-to-date but will always lag behind new plant introductions.” Since 1995, the Bishop Museum Occasional Papers series has published observations of newly naturalized non-native plants annually (e.g. Frohlich & Lau, 2008; Oppenheimer, 2008; Starr *et al.*, 2008), and a website maintained by Forest and Kim Starr documents many introduced plants of Hawaii.[15]

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[13] http://botany.si.edu/pacificislandbiodiversity/hawaiianflora/specs.cfm

[14] www2.bishopmuseum.org/HBS/botany/cultivatedplants/

[15] www.hear.org/starr

But overall we have little idea what species are already present in Hawaii. An article in the Dec. 2006-Jan. 2007 Hawaiian Airlines magazine, Hana Hou![16] stated that one person has 10,000 taxa of plants on 3 acres of land above Hilo; another is said to have 800 taxa of palms on 6 acres in Kurtistown. At this point in time, we have scant knowledge of what plant species are in cultivation in Hawaii.

Resources for identifying potentially invasive plant species for the Hawaiian Islands

The two most comprehensive compilations of information on invasive plants species currently are Ewald Weber's (2003) "Invasive plant species of the world: A reference guide to environmental weeds" and Rod Randall's (2002) "Global compendium of weeds" (GCW), with online availability and updating.[17] Further, a database of problematic invasive plants on oceanic islands around the world has recently been published, including some 400 spermatophyte plants (Kueffer et al. 2009). Weber's book provides concise analyses of 448 plant species that are invasive in natural areas of at least one region of the world. An updated database currently includes information on some 800 species (E. Weber, pers. comm.). Randall's GCW is more inclusive than Weber's book; it is a list/database of weed species and invasive species references, with about 28,000 plant names based on ca. 1,000 references. All types of weeds are included, not just environmental weeds. Further databases on invasive plants can be accessed through the HEAR website[18] and are listed on the Global Invasive Species Program's website.[19]

Early detection

The concept of early detection and rapid response (EDRR) to incipient plant invaders has been promoted internationally, nationally, and locally as a potentially cost effective strategy in addressing plant invasions (Kueffer & Hirsch Hadorn, 2008; Simberloff, 2003; Westbrooks, 1993; Wittenberg & Cock, 2001).[20] Rejmanek (2000) stated: "In

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[16] www.hanahou.com

[17] www.hear.org/gcw

[18] www.hear.org/

[19] www.gisp.org/links/index.asp

[20] See also www.pwrc.usgs.gov/brd/invasiveHandbook.cfm

general, all models and empirical data suggest that even a moderate increase in resources for early detection and eradication of invasive weeds would be a profitable investment." EDRR has been recognized as an important tool in Hawaii for over 20 years, dating back at least to early efforts in and around Haleakala National Park (Loope, 1992). Experience from early detection on the island of Maui may shed light on an effective approach toward making the most of a state restricted list. Maui Invasive Species Committee (MISC) has used early detection for almost a decade to identify "low hanging fruit" for eradication. Aggressive but incipient invasive species such as *Melastoma candidum, Parkinsonia aculeata*, *Rhodomyrtus tomentosa*, *Rubus ellipticus*, and *Verbascum thapsus* have been eradicated from Maui, at least in the sense that all known individuals have been removed, with continued surveillance (Loope *et al.*, 2004). A nursery survey effort currently underway on Maui (Starr *et al.*, in review-a) has documented over 300 new state records of cultivated plant species on the island of Maui. This approach may at least begin to provide a model for how to determine what potentially invasive species are in the state and how to work with the industry and the public to optimize regulation and compliance. Information from early detection efforts can help provide transparency in the give and take with stakeholders leading to rational decisions on what species will be restricted.

Methodology used to date by the ISCs for early detection of invasive plant species in Hawaii involves the so-called "nursery survey" and "roadside survey" (Starr *et al.*, in review-a, b).

Nursery survey

"Nurseries," in the broad sense used here, are areas where cultivated plants can be found in high concentrations, such as retail and wholesale nurseries, botanical gardens, public parks, arboreta, and private gardens. The more accurate but relatively unwieldy term "plant distribution center" has been used for this same concept by Welch (2007). A "nursery survey" is a listing of plants found within a nursery. Nursery surveys help build a record of plants found in an area, with an emphasis on finding new and (potentially) invasive plants.

Nurseries are often where species enter the state or an island for the first time, i.e. they are the main foci for distribution of non-native plants. The general pattern of invasion has been intentional long-distance introduction to a public or private garden and then intentional local spread to secondary sites--often human habitations--then into nearby open habitats, primarily by dispersal of seeds by birds or by wind. This pattern of introduction and spread suggests that systematic surveys of nurseries would reveal the presence of potentially invasive non-native plants much earlier than through incidental observations.

Nursery surveys help answer the following questions:

- What plants are in an area? An effective means of getting a handle on the potentially invasive plant species in an area is to create a list of plants known to be present. Nursery surveys contribute in a major way to accomplishing this task.
- What plants are new to an area? Along with baseline lists, nursery surveys provide an early detection opportunity. New and novel plants can often be found for the first time in nurseries. Regular surveys of nurseries will result in new plant records.
- What plants are known to be invasive? Once a list of species in nurseries is gathered, analysis can be applied to that list by highlighting which species in nurseries have been considered invasive somewhere in the world. More detailed analysis can follow, through weed risk assessment and evaluation of evidence of impacts in the literature.

A major potential obstacle for early detection nursery surveys is that there is no legal basis that allows early detection teams to enter private land or that forces plant importers/distributors/sellers to label their plants. To date, most nurseries on Maui have been highly receptive to allowing surveys.

Roadside surveys

"Roadside survey," as used here, is a generic term for a botanical survey that entails driving roads while recording locations for target species. "Roads" can be paved streets, four wheel drive roads, or even trails. In general though, roads are considered here to mean paved, publicly-accessible transportation corridors.

Roads provide repeatable transects through areas of human habitation and can be an efficient way to map species distribution and monitor newly introduced plant species. Searching along roads can be effective because most human habitations (sites of secondary foci of newly invasive species) occur along roads, and vast distances can be covered with minimal effort.

The core methodology is to drive roads at 5-10 mph, recording target species locations. Once all the roads have been surveyed, distribution maps are produced for each species. These maps are further refined through interviews with local botanists.

Roadside surveys help answer the following questions:

- Where are target species located? Distribution maps provide a visual island-wide view of locations and can help reveal how widespread a plant is, patterns of spread, and outlier populations

- Is eradication or containment feasible at this time? Distribution is one of the main factors considered when determining whether eradication or containment of non-native plants is a feasible option. Roadside surveys help to reveal locations and can contribute to informed decisions for eradication or containment.

Long term management of invasive plant species in Special Ecological Areas at Hawaii Volcanoes National Park– A review of the last 20 years, or where do we go from here?

By Rhonda Loh and Tim Tunison

In Hawaiʻi Volcanoes National Park, management units called Special Ecological Areas (SEAs) (Tunison & Stone, 1992) are established to control 20+ highly disruptive invasive species perceived to be too widespread for parkwide eradication to be feasible. SEAs are prioritized for intensive weed management based on their 1) representativeness of a particular ecological zone or rarity of vegetation type, 2) manageability, i.e. areas are accessible, and the potential for native species recovery is high, 3) species diversity and rare species, and 4) value for research and interpretation. Also important to the SEA concept is its flexibility. So while initial weed control may focus on only a handful of the best areas, the number and size of units can be expanded as additional resources are made available.

In 1985, the first six SEAs and a buffer unit (total area ca 12,000 ac) were established in wet ʻōhiʻa/hapuʻu forest, mesic koa forest, and dry ʻōhiʻa woodland. Inside each unit, ground crews systematically searched and removed as many as eleven target weed species within an area. Control methods varied from manual uprooting to chemical treatments depending on species. In some open vegetated areas where infestations were low, helicopter searches assisted ground crews in locating and removing weeds. After initial treatment of weeds, crews revisited sites at one to five year return intervals to remove any new weeds that re-established from seeds that persisted in the soil or dispersed from nearby areas. Over the next two decades, increased funding was made available and the number and size of SEAs were expanded. By 2007, 27 SEAs covering over 66,000 ac were managed for target weeds in the park. These included several more degraded areas that served as buffer units to reduce seed dispersal of weeds into adjacent SEAs that were more intact.

Typically, initial knockdown of weeds (knockdown phase) was followed by subsequent revisits to keep infestations at low or manageable levels (maintenance phase) in SEAs. The time to get from the knockdown to the maintenance phase depended on 1) the initial level of weeds within a unit, and 2) how frequently sites were revisited. For example, SEAs with initially very low levels of weed infestations either began at maintenance levels (e.g. Small Tract) or required only one or two treatment re-visits to reach maintenance levels (e.g. Keamoku). Whereas, units with higher amounts of weeds and longer intervals between treatments took as many as four or five revisits across ten years before reaching maintenance levels (e.g. Thurston and Puaulu Buffer). The level of weed infestation at the maintenance phase varied depending on vegetation type, the size of the unit, and the amount of weeds in nearby areas. For example, in dry ‘ōhi‘a woodlands, maintenance levels of invasive plants (e.g. firetree – *Myrica [Morella] faya*, Russian olive – *Eleagnus angustifolia*) was ~ 10 individuals/ac in ‘Āinahou, a 46 ac unit surrounded by dense firetree forest, and less than 1 individuals/ac in Hilina Pali, a 1,100 ac unit. In wet forest units, maintenance levels of all target weeds (e.g. kahili ginger, banana poka – *Passiflora tarminiana*, Himalayan raspberry and others) converged toward ~100 individuals/acre. Finally, the size of invasive individuals decreased and fewer mature individuals were encountered as units moved from knockdown to maintenance levels.

A shift from knockdown to maintenance weed levels was accompanied by a drop in labor cost as fewer worker days were spent searching and removing individuals from a management area. For wet forest, this resulted in a nearly five-fold decrease in labor dollars spent in the field ($756/ac to $156/ac in 2007 dollars). In dry open habitats where weed levels were very low, costs could be further reduced by replacing ground crews with helicopter crews to search and chemically treat individuals from the air ($40/ac to $1/ac, the latter includes helicopter rental cost).

This reduction in $ labor cost/ac as SEAs move from knockdown to maintenance phase, allowed for the expansion of the weed control program. Between 1985 and 2007, acreage in SEAs expanded from 12,000 ac to ac 66,000 ac, a 500% increase in area (Figure 1). Labor cost spent in the field searching and removing weeds increased only about 50% (in 2007 dollars, Figure 2). This translated to a three-fold decrease in $ labor cost/ac ($11.60/ac in 1985 to $3.40/ac in 2007), with wet forest being the most expensive ($156/ac) and dry ‘ōhi‘a woodland the least expensive ($1/ac including helicopter rental).

Expansion of SEAs is possible when initial populations can be significantly reduced and maintained at very low levels; recruitment of alien plants is low; and work loads drop significantly after initial control efforts. Weaknesses of the SEA approach are that follow-up treatment is required indefinitely, surrounding areas will increase in alien plant densities and recruitment may become unmanageable if areas are too small. Managers are challenged to maximize program effectiveness by optimizing intervals between follow-up treatments, applying new search and control technology, and developing partnerships with the community and adjacent landowners to expand management areas, create buffer zones and reduce seed dispersal from nearby areas.

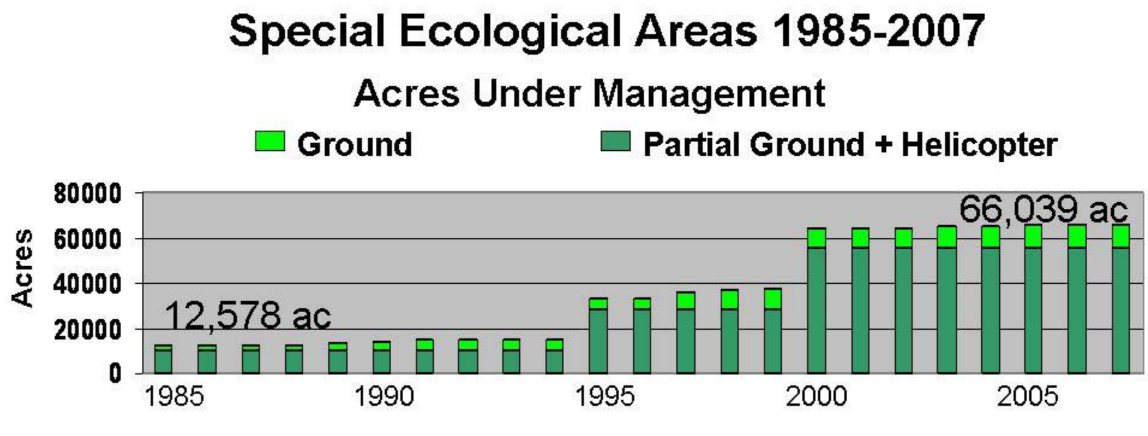

Fig. 1: Acres under SEA management at Hawai‘i Volcanoes National Park, 1985-2007.

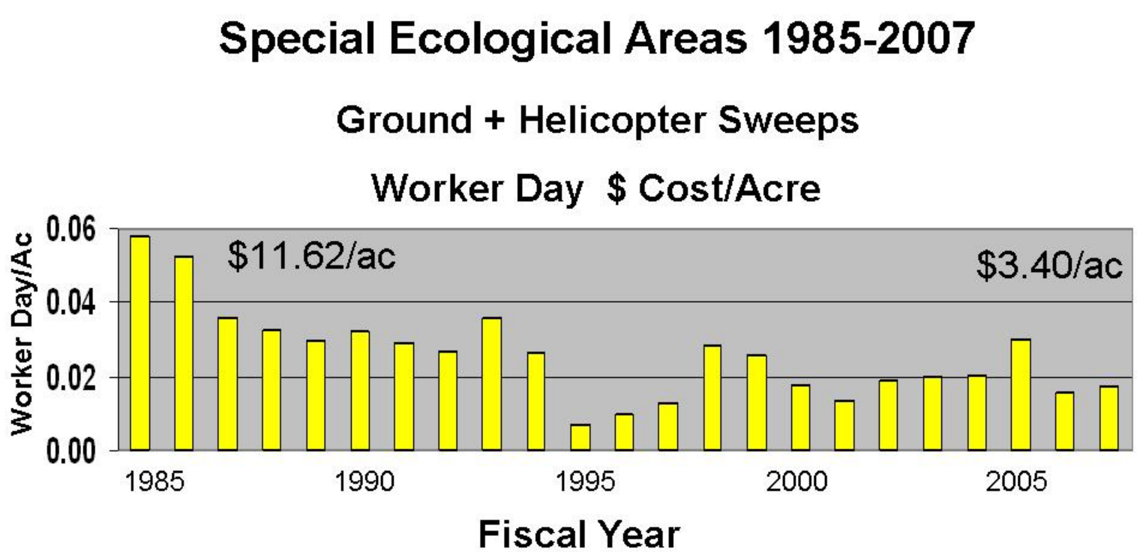

Fig. 2: Labor +helicopter cost ($/acre) spent searching and treating invasive plants from SEAs, 1985-2007. Costs were adjusted to reflect 2007 dollars.

Miconia calvescens: a case example of the need for prevention and early detection in the Hawaiian Islands

By Lloyd Loope

The history of *Miconia calvescens* in Hawaii has perhaps done more than anything to stimulate interest in island-wide early detection and eradication/containment of invasive plant species (Conant *et al.*, 1997). Miconia had been known on the Big Island since the early 1970s. Miconia's aggressive invasiveness in Tahiti in a high-island environment very comparable to rain forest environments of Hawaii was first reported to Hawaii by Dr. Raymond Fosberg in 1971. This gathering storm became increasingly well known in Hawaii through the 1980s, but no sustained action was taken until Maui's efforts coalesced in 1991 and a "Melastome Action Committee" was formed. The effort was assisted by solid documentation of the dramatic impacts of miconia in Tahiti (Meyer, 1996; Meyer & Florence, 1996).

Maui responded soon after miconia was discovered there but still probably about 20 years late (based on its relatively widespread distribution when "discovered"). The Maui Invasive Species Committee still spends about half its $2 million annual budget keeping miconia contained, with the rationale that one cannot take for granted that biological control of miconia will be successful. Oahu and Kauai spend much less on miconia because its invasive spread was responded to at an earlier stage of invasion there. (Although miconia had been recognized as naturalized on Oahu since the 1970s, it was not discovered on Kauai until 1995.) Molokai has been surveyed and still apparently lacks miconia. Miconia spread has burgeoned on the Big Island to the point that the primary strategy for the Big Island Invasive Species Committee (BIISC) now involves containment in buffer zones around the periphery of its range. Biological control is seen by many as the only acceptable long-term solution to addressing miconia in Hawaii; biocontrol exploration and testing efforts started at least 15 years ago and several promising biocontrol agents are in the works. If biocontrol were to succeed for miconia, it might be much easier for the ISCs to more successfully address a broader range of targets.

Remote sensing

There are currently two complementary remote sensing systems in place in Hawaii that may be of value for invasive species management.

Resource Mapping Hawaii[21] produces very high resolution images (max. resolution: multispectral 4 bands: 20 cm per pixel; natural color, 3 bands: 1-2 cm per pixel) that are particularly valuable for visual interpretation by an expert, e.g. for early detection or mapping of alien species.

The Carnegie Airborne Observatory (CAO)[22] produces hyperspectral, 350 bands imagery (resolution: 30 cm) and full waveform LIDAR that allow for automated analysis of vegetation composition and structure (incl. understory and 3D structure), and physiology (incl. ecosystem impacts of invasive species).

Species distribution modeling (SDM)

By Christoph Kueffer & Curt Daehler

Species distribution modeling (SDM) attempts to predict the distribution of species in the landscape. Niche (or bioclimatic envelope) modeling is one SDM modeling approach. It is based on the assumption that the environmental space in which a species will grow (niche or bioclimatic envelope) can be determined based on the observed presences and absences of the species in the landscape, which for instance can be determined based on field surveys (typically presences and absences) or herbarium records (typically only presences).

A number of modeling software packages are freely available for SDM (e.g. Maxent[23], or Biomod[24]). Species distribution data (e.g. GBIF[25]) and climate data (e.g. Worldclim[26], PRISM[27]) are also increasingly becoming available for free.

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[21] http://resourcemappinggis.com/

[22] http://cao.stanford.edu/

[23] www.cs.princeton.edu/~schapire/maxent/

[24] http://r-forge.r-project.org/projects/biomod/

[25] www.gbif.org

[26] www.worldclim.org/

SDM may predict potential habitat in an area based on species distribution data from the same area, or it may use models prepared based on species distribution data from one area to predict occurrences in another area. In the case of invasive species one application is to model the distribution of a species in a (potential) area of introduction based on distribution data from the native range. SDM can also predict potential future distributions of species based on climate change scenarios. The reliability of predictions based on transferred models (from native to introduced range, or with climate change) depends on a number of assumptions of SDM, especially that the species has reached an equilibrium distribution in the area from which data for preparing the model is collected ("fitted area"), that the same environmental factors determine the distribution of a species in the fitted and predicted area, and that the complete distribution in the fitted area is represented in the dataset used to prepare the model. Therefore SDM model predictions must always be checked carefully, and their reliability may differ considerably between models as well as between species modeled with the same model.

To date, most SDM approaches use mainly or exclusively climate factors to predict species distributions. Currently, models are being developed that include other abiotic factors (e.g. soil, habitat type) as well as biotic factors (e.g. co-occurring competitors). Another current development is to move from predicting potential presence and absence of invasive species to predicting the potential distribution of impacts of invasive species (Daehler & Kueffer, in prep.).

SDM may be of use to invasive species management in all management phases from prevention to early detection and containment. SDM can help to determine if an alien species is native or has shown to be invasive in an area with a similar climate to Hawaii (climate matching) and thereby improve weed risk assessments. However, because most world climates are present on the Hawaiian Islands, combined with the very small size of the Hawaiian Islands, this may be of limited use at the state-wide level. More important may be that SDM can predict where a species may become invasive within the Hawaiian Islands, and such predictions may be most valuable for awareness building and social marketing. For early detection, SDM may predict the areas of highest probability of occurrence for a new species, as well as the effectiveness of a particular search strategy (e.g. by predicting the area where 99% of the occurrences of a species are likely to be found). For containment, species distribution prediction maps can be combined with other GIS layers (e.g. extent of natural area, landowners, etc.) to plan containment and control efforts. Further, it can be determined based on an SDM model if a new infestation of a species occurs within the expected climate space. If not, this may possibly be an indication that a new genotype with novel environmental preferences has established, and such satellite populations in environmental space may be eradicated as a first priority (compare paragraph on genetics below).

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[27] www.prism.oregonstate.edu/

Using ecological genetics and molecular tools to improve our understanding of invasive species

By Gabi Jakobs

Initially, the spread of invasive species is dependent on pre-adaptation to local conditions (e.g., climate, soil). Molecular techniques can reveal the origin of introduced populations, and they can help identify vectors of introduction and spread, which allows targeting and management of high-risk vectors.

In the invaded habitat, introduced species usually experience an array of novel selection pressures, which may trigger them to rapidly evolve. Recent studies indicate the significance of additive genetic variance as a stimulus for adaptive changes, particularly in life-history traits (e.g. time to germination, flowering time). Hybridization between closely related introduced or introduced and native species can increase additive genetic variance (resulting in higher phenotypic diversity) and heterozygosity (more individuals having different alleles for the same gene); this can allow some hybrid lineages to have wider ecological niches or higher competitive abilities than either of the parent species.

Multiple introductions may also provide genetic resources necessary for adaptation to novel environments, thus efforts should be directed towards preventing secondary introductions. Several invasive species and introduced pests have been shown to be invasive only after repeated introductions, resulting in higher genetic diversity and accordingly higher evolutionary potential. These allow for adaptations as we found in introduced out-breeding species along the altitudinal gradients of Mauna Kea and Haleakala (Jakobs et al., in prep.); in contrast selfing species introduced at a similar time did not show specific adaptations and the evolutionary time might be too short for such species with limited gene exchange.

Assuming fast evolutionary adaptations, control efforts should target populations at the population margins that experience more extreme conditions so as to limit the potential for adaptation (compare also paragraph on species distribution modeling above). In contrast, if the invasiveness of a species is defined by a wide phenotypic plasticity (general purpose genotype), eradication efforts may first focus on populations with the highest reproductive output (often central populations), especially when the invader has wide dispersal ability, because the most vigorous populations are likely to contribute disproportionately to the spread of the invader.

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Appendix

Abbreviations

BIISC	Big Island Invasive Species Committee
CGAPS	Coordinating Group on Alien Pest Species
EDRR	Early detection and rapid response
GCW	Global Compendium of Weeds
HASLA	Hawaii Chapter of the American Society of Landscape Architects
HEPEP	Hawaii Exotic Plant Evaluation Protocol
HP-WRA	Hawaii-Pacific Weed Risk Assessment
ISC	Invasive Species Committee
KISC	Kauai Invasive Species Committee
MISC	Maui Invasive Species Committee
MoMISC	Molokai Invasive Species Committee
NPPA	New Zealand National Plant Pest Accord
OISC	Oahu Invasive Species Committee
SDM	Species distribution modeling
SEA	Special Ecological Area
HDOA	Hawaii Department of Agriculture

Symposium and workshop schedule

Symposium

Lloyd Loope - Toward a rationale and strategy for a collaborative statewide program of early detection of incipient invasive plant species in Hawaii

Rhonda Loh - Long term management of invasive plant species at Hawaii Volcanoes National Park– a review of the last 20 years, or where do we go from here?

Gabi Jakobs & Curtis C. Daehler - Genetics provide valuable insights into species invasions

Christoph Kueffer & Curtis C. Daehler - Predicting the potential spatial distribution of invasive alien plants with niche modeling: concepts and applications.

Workshop

Christoph Kueffer – Introduction

Christy Martin - 2008 Plant Industry Survey: Hawai‘i Pacific Weed Risk Assessment -

Codes of Conduct - HASLA Invasive Plant Initiative.

Keren Gundersen - Prioritization of Environmental Weeds for Different Management Strategies.

Teya Penniman - Invasive Species Committees: Containment Strategies & Tools.

Lori Buchanan, Keren Gundersen, Julie Leialoha, Rachel Neville & Teya Penniman - Round Table. The Experiences of the Invasive Species Committees (ISC).

Curt Daehler - Objective Assessment of Invasive Plant Risks and Impacts: Why and How?

Chris Dacus & Boyd Ready - Hawai'i Chapter ASLA Invasive Initiative

Christopher Buddenhagen – The New Zealand Approach

Philip Thomas – Cohesive and Comprehensive Quarantine/Biosecurity Legislation for Hawaii

List of participants

Ambagis	Stephen	U.S. Geological Survey – HCSU
Ansari	Shahin	SWCA Environmental Consultants
Benitez	David	Hawaii Volcanoes National Park
Bresell	Michael	Ko'olau Mountain Watershed Partnership (KMWP)
Buchanan	Lori	Molokai Invasive Species Committee
Buddenhagen	Christopher	Hawaii Invasive Species Council
Buermeyer	Karl	US Fish and Wildlife Service
Campbell	Earl	US Fish and Wildlife Service
Chimera	Charles	Hawaii Invasive Species Council (HWRA) - Maui
Coleman	Martha	University of Hawaii at Manoa
Conant	Pat	Hawaii Department of Agriculture (HDOA)
Dacus	Chris	State Department of Transportation
Daehler	Curt	University of Hawaii at Manoa
Denslow	Julie	Institute of Pacific Islands Forestry
Else	Page	HCA Environmental Data Analyst
Franklin	Jean K.	Big Island Invasive Species Committee
Frohlich	Danielle	Oahu Early Detection
Gundersen	Keren	Kauai Invasive Species Committee
Harrison	Sky	Pacific Basin Information Node (PBIN)
Jakobs	Gabi	University of Hawaii at Manoa
Kau	Ella Garcia	University of Hawaii at Manoa
Kueffer	Christoph	University of Hawaii at Manoa
LaRosa	Anne Marie	Institute of Pacific Islands Forestry
Lau	Alex	Oahu Early Detection
Leary	James	University of Hawaii at Manoa
Leialoha	Julie	Big Island Invasive Species Committee
Loh	Rhonda	Hawaii Volcanoes National Park
Loope	Lloyd	U.S. Geological Survey
Martin	Christy	CGAPS-Coordinating Group on Alien Pest Species
McGuire	Raymond	Big Island Invasive Species Committee
Menard	Trae	The Nature Conservancy on Kauai
Neville	Rachel	Oahu Invasive Species Council
Oishi	Darcy	Hawaii Department of Agriculture (HDOA)
Parker	James	Big Island Invasive Species Committee
Penniman	Teya	Maui Invasive Species Committee
Price	Jonathan	University of Hawaii Hilo
Ready	Boyd	Landscape Industry Council
Reimer	Neil	Hawaii Department of Agriculture (HDOA)
Schumacher	Eva	University of Hawaii at Manoa
Thomas	Philip	Hawaiian Ecosystems at Risk project (HEAR)