Invasions and impacts of exotic plants in the Pacific islands

Julie S. Denslow
Institute of Pacific Islands Forestry, USDA Forest Service, 60 Nowelo Street, Hilo, HI 96720, USA
e-mail: jdenslow@fs.fed.us

Summary Islands support many more species of invasive plants than comparably sized mainland habitats. Analysis of extensive data on the distribution of invasive plants among Pacific islands suggests that the diversity of these species on islands is a function of both environmental characteristics (island size, habitat heterogeneity) and socioeconomic conditions (country identity, *per capita* gross domestic product, presence of airports with paved runways, human population size and density). The spread and impact of invasive species on islands also are likely affected by the juxtaposition of agroforestry operations and forest boundaries, by native floras whose competitive capacity is low and/or reduced by loss of pollinators and dispersal agents, and by the ability of some invasive species to alter ecosystem structure and function in fragile island landscapes.

Islands also lack many of the necessary resources to respond effectively to the spread and impacts of invasive plants. Countries with more resources should be mindful of the potential impacts of exported species on small island ecosystems and seek ways to bolster resources of island governments in the management of invasive species.

Keywords Islands, diversity, management, restoration.

INTRODUCTION

The vulnerability of oceanic islands to naturalisation of exotic species is well known. Sax and colleagues (Sax *et al*. 2002, Sax and Gaines 2003) estimated that oceanic islands had twice as many naturalised exotic plant species as comparably-sized patches of mainland landscapes. Tropical Pacific islands comprise socioeconomic variation in population size, economic and cultural history, cultural diversity, and annual income interlaced with environmental variation produced by differences in substrate, topography, size, elevation, isolation, native species richness, and climate among others. Steep environmental gradients on the high volcanic islands produce high habitat heterogeneity at relatively modest spatial scales. Here I explore some of the factors affecting the diversity and impacts of invasive exotic plants in Hawai'i and the Western Pacific Islands. I highlight results of research conducted through the Institute of Pacific Islands Forestry of the USDA Forest Service.

DIVERSITY AND DISTRIBUTION

James Space and his collaborators (Space 2005) have assembled extensive information on the distribution of more than 1100 species of exotic invasive plants in the Pacific Islands (www.hear.org/pier). While this is not an exhaustive list of exotic plants in the Pacific, it provides insights into factors affecting the distribution and spread of some of the most noxious. We used AICc analysis (Burnham and Anderson 2002) to assess alternative models for the richness of PIER-listed species on 114 islands in 15 countries and states where our data were most reliable (Denslow *et al*. submitted). Variables included in the strongest models at the island level were area (as log(area)), maximum elevation (an index of habitat heterogeneity), country or political unit and the presence of an airport with paved runway. At the country or state level, area (as log(area)), *per capita* gross domestic product, and population (as total population size or population density) were included in the best models. These analyses suggest that exotic species may be affected by environmental and biogeographic factors in much the same way as native species. Resource availability, productivity, area and habitat heterogeneity are correlated with high native species richness (e.g., Ricklefs and Lovette 1999, Pyšek *et al.* 2002, Price 2004, Jarnevich *et al*. 2006) and we expect they will be similarly correlated with exotic richness. The richness of PIER-listed species also was significantly correlated with native species richness (Denslow *et al.* submitted) as found for native and exotic species elsewhere (Lonsdale 1999, Stohlgren *et al*. 1999, Levine 2000, Richardson *et al*. 2005). In our study socioeconomic factors also affected invasive species richness as evidenced by the inclusion of variables associated with economic activity and population size in the models. High economic activity also likely reflects disturbance, trade in exotic species, and agricultural and forestry activity. Country-state identity also has a significant impact on numbers of PIER-listed species on islands. For example Hawaiian islands have 50 more species than other islands, whereas New Caledonian and Fijian islands have 59 and 45 fewer species, respectively (Denslow *et al.* submitted). Political units are likely to share many factors that may influence introduction and spread of invasive species including culture, immigration histories, agricultural, forestry and reforestation initiatives, levels of economic development and trading patterns.

SPREAD AND IMPACT

On islands, the boundary between wild and managed landscapes is often blurred. A long tradition of agroforestry at the forest edges heightens the risk of crossover impacts of invasive species. It is well known that activities at the urban/wildland interface can strongly affect the spread of invasive exotic species into wildland ecosystems. Many weed species known to be invasive in wildlands were originally introduced for horticultural, forestry, or agricultural purposes (Daehler and Carino 1999, Mack *et al*. 2002). Human settlements, gardens, roads and trails promote the spread of invasive species into adjacent wildlands (e.g., Sullivan *et al.* 2005). The traffic is not all one way however. In Hawai'i, strawberry guava (*Psidium cattleianum* Sabine (Myrtaceae)) fruits are an important resource for the oriental fruit fly (*Bactrocera dorsalis* (Diptera: Tephritidae), pests with major agricultural impacts on papaya and other soft fruits (McGregor 2004). Fruit fly populations are substantially bolstered by access to fruits of strawberry guava and its congener, *P. guajava* L.*,* which have widely invaded forest reserves and fallow lands (Vargas *et al.* 1989). In wildlands, strawberry guava alters forest structure and increases management costs. Another example is *Falcataria moluccana* (Miq.) Barneby & J.W.Grimes (Fabaceae, albizia), a large (to 40 m tall), nitrogen-fixing tree widely planted in the Pacific Islands. In Hawai'i and elsewhere it has had a particularly severe impact on native forests colonising nutrient-poor soils where it facilitates the establishment of other exotics such as *Psidium cattleianum*, *Clidemia hirta* (L.) D.Don., and *Melastoma candidum* D.Don (Hughes and Denslow 2005). Land owners at the suburban/forest boundary find that albizia from seed dispersed from wildland populations rapidly colonise cleared land creating a tall canopy within a short time. These trees pose a substantial risk to structures and people because of the brittle nature of their wood and the high costs incurred for their removal.

IMPEDIMENTS TO RESTORATION

On islands, effective management of invasive plants may be impeded by disharmonies in the native flora and fauna. Native plant communities may be highly invasible even when largely intact and undisturbed. The composition, growth form, and growth rates of native species may make them ineffective competitors for space and resources. Hawaiian forests dominated by native species often have relatively open canopies allowing substantial light to reach the ground. The canopy dominant in many Hawaiian forests, *Metrosideros polymorpha* Gaud. (Myrtaceae), grows slowly even where resources are plentiful, making it a poor competitor with rapidly growing exotic species (Denslow and Uowolo unpub). In addition, loss of native pollinators and dispersal agents, coupled with the introduction of generalist plant pests, has reduced the regenerative capacity of native species. Thus, while competition from invasive species, such as exotic grasses, may reduce establishment rates, weed removal may not result in a sufficiently closed forest of native species to provide resistance to new invasions (Cabin *et al.* 2002, Denslow *et al*. 2006).

Island ecosystems may be less resilient to the impacts of invasive exotic plants which alter disturbance regimes, nutrient supply and other ecosystem processes because they introduce new growth forms or functional groups into disharmonic island communities (Vitousek 1986). The introduction of exotic grasses and rangeland forbs in support of ranching and horticulture fosters a cycle of grass and fire that is difficult to break and has long-term consequences for ecosystem structure and landuse in landscapes where fire historically played a minor role (D'Antonio and Vitousek 1992). Similarly the use of nitrogen-fixing legumes for reforestation as in the case of *Leucaena leucocephala* (Fabaceae) on Guam, may effectively preclude the establishment of native pioneers and arrest a natural succession in native species.

CONCLUSIONS

By their nature, islands generally are characterised by limited ecosystems, economies, and resources, creating a challenge for the management of a flood of potentially invasive species across their borders. Lack of resources …funds, personnel, information, infrastructure… severely limit local capacity to address an invasive threat to the health of native and managed ecosystems. The history of island societies is one of the movement of people and their resource species, from the earliest voyagers to the post World War II and modern efforts of foreign powers to restructure island ecosystems and economies (Elevitch and Wilkinson 2000). In an era of global economies and trade, it is incumbent on large economies to be mindful of the vulnerability of small economies in our zeal to export promising species and to promote projects with seemingly promising environmental and economic benefits. We should look for opportunities to share information on potentially invasive species, to cooperate in development and evaluation of biological control agents for shared weeds, and to limit or at least carefully evaluate exports of species to islands for agricultural, forestry, restoration, or horticultural purposes to avoid contributing to the impacts of invasive exotic species on fragile island ecosystems and economies.

ACKNOWLEDGMENTS

I am grateful for an early on-the-ground introduction to issues of invasive plant management in the Pacific Islands by Jim Space (USDA FS, retired) and Barbara Waterhouse (AQIS) and for the support of the USDA Forest Service Institute of Pacific Islands Forestry.

REFERENCES

Burnham, K.P. and Anderson, D.R. (2002). Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. (Springer, New York, USA).

Cabin, R.J., Weller, S.G., Lorence, D.H., Cordell, S., Hadway, L.J., Montgomery, R., Goo, D. and Urakami, A. (2002). Effects of light, alien grass and native species additions on Hawaiian dry forest restoration. *Ecological Applications* 12, 1595-610.

Daehler, C.C. and Carino, D.A. (1999). Threats of invasive plants to the conservation of biodiversity. *In* Biodiversity and allelopathy: from organisms to ecosystems in the Pacific, eds C.H. Chou, G.R. Waller and C. Reinhardt, pp. 21-27. (Academica Sinica, Taipei).

D'Antonio, C.M. and Vitousek, P.M. (1992). Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecology and Systematics* 23, 63-87.

Denslow, J.S., Space, J.C. and Thomas, P.A. (Submitted). Invasive exotic plants in the Pacific islands: correlates of species richness. *Biotropica*.

Denslow, J.S., Uowolo, A.L. and Hughes, R.F. (2006). Limitations to seedling establishment in a mesic Hawaiian Forest. *Oecologia* 148,118-28.

Elevitch, C.R. and Wilkinson, K.M. eds. (2000). Agroforestry guides for Pacific Islands. Permanent Agriculture Resources, Permanent Agricultural Resources, Holualoa, Hawai'i, USA.

Hughes, R.F. and Denslow, J.S. (2005). Invasion by a N_2-fixing tree alters function and structure in wet lowland forests of Hawai'i. *Ecological Applications* 15, 1615-28.

Jarnevich, C.S., Stohlgren, T.J., Barnett, D. and Kartesz, J.T. (2006). Filling in the gaps: modelling native species richness and invasions using spatially incomplete data. *Diversity and Distributions* 12, 511-20.

Levine, J.M. (2000). Species diversity and biological invasions: relating local process to community pattern. *Science* 288, 852-4.

Lonsdale, W.M. (1999). Global of plant invasions and the concept of invasibility. *Ecology* 80, 1522-36.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H. and Clout, M. (2002). Biotic invasions: causes, epidemiology, global consequences and control. *Ecological Applications* 10, 689-710.

McGregor, A.M. (2004). An economic evaluation of the Hawai'i fruit fly Area-Wide Pest Management Program: an interim report. Trade and Development Office, Suva, Fiji.

Pyšek, P., Kučera, T. and Jarošik, V. (2002). Plant species richness of nature reserves: the interplay of area, climate and habitat in a central European landscape. *Global Ecology and Biogeography Letters* 11, 279-89.

Richardson, D.M., Rouget, M., Ralston, S.J., Cowling, R.M., Van Rensburg, B.J. and Thuiller, W. (2005). Species richness of alien plants in South Africa: environmental correlates and the relationship with indigenous plant species richness. *Ecoscience* 12, 391-402.

Ricklefs, R.E. and Lovette, I.J. (1999). The roles of island area *per se* and habitat diversity in the species-area relationships of four Lesser Antillean faunal groups. *Journal of Animal Ecology* 68, 1142-60.

Sax, D.F., Gaines, S.D. and Brown, J.H. (2002). Species invasions exceed extinctions on islands worldwide: a comparative study of plants and birds. *American Naturalist* 160, 766-783.

Sax, D.F. and Gaines, S.D. (2003). Species diversity: from global decreases to local increases. *Trends in Ecology and Evolution* 18, 561-6.

Space, J.C. (2005). Pacific Island Ecosystems at Risk. V. 5.0. USDA Forest Service, Institute of Pacific Islands Forestry, Hilo, HI.

Stohlgren, T.J., Binkley, D., Chong, G.W., Kalkhan, M.A., Schell, L.D., Bull, K.A., Otsuki, Y., Newman, G., Bashkin, M. and Son, Y. (1999). Exotic plant species invade hot spots of native plant diversity. *Ecological Monographs* 69, 25-46.

Sullivan, J.J., Timmins, S.M. and Williams, P.A. (2005). Movement of exotic plants into coastal native forests from gardens in northern New Zealand. *New Zealand Journal of Ecology* 29, 1-10.

Vargas, R.I., Stark, J.D. and Nishida, T. (1989). Abundance, distribution, and dispersion indices of the oriental fruit fly and melon fly on Kauai, Hawaiian Islands. *Journal of Economic Entomology* 82, L609-L6L5.

Vitousek, P.M. (1986). Biological invasions and ecosystem properties: can species make a difference. *In* 'Ecology of biological invasions of North America and Hawai'i', eds H.A. Mooney and J.A. Drake, pp. 163-76. (Springer-Verlag, New York).