Weed Risk Assessment for *Hedychium gardnerianum* Sheppard ex. Ker Gawl (Zingiberaceae) – Kahili ginger lily

United States Department of Agriculture

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Version 1

Left: *Hedychium gardnerianum* flowers (source: Forest and Kim Starr, www.hear.org/starr/). Upper right: A dense stand of *H. gardnerianum* along a roadside in New Zealand (source: Walter Stahel, Environment B.O.P, NZ). Lower right: The understorey in parts of Olinda, Maui has been overtaken by *H. gardnerianum* (source: Forest and Kim Starr, www.hear.org/starr/).

Agency Contact:
Plant Epidemiology and Risk Analysis Laboratory
Center for Plant Health Science and Technology

Plant Protection and Quarantine
Animal and Plant Health Inspection Service
United States Department of Agriculture
1730 Varsity Drive, Suite 300
Raleigh, NC 27606

Introduction Plant Protection and Quarantine (PPQ) regulates noxious weeds under the authority of the Plant Protection Act (7 U.S.C. § 7701-7786, 2000) and the Federal Seed Act (7 U.S.C. § 1581-1610, 1939). A noxious weed is defined as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" (7 U.S.C. § 7701-7786, 2000). We use weed risk assessment (WRA) - specifically, the PPQ WRA model (Koop et al., 2012) - to evaluate the risk potential of plants, including those newly detected in the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

Because the PPQ WRA model is geographically and climatically neutral, it can be used to evaluate the baseline invasive/weed potential of any plant species for the entire United States or for any area within it. As part of this analysis, we use a stochastic simulation to evaluate how much the uncertainty associated with the analysis affects the model outcomes. We also use GIS overlays to evaluate those areas of the United States that may be suitable for the establishment of the plant. For more information on the PPQ WRA process, please refer to the document, *Background information on the PPQ Weed Risk Assessment*, which is available upon request.

Hedychium gardnerianum Sheppard ex. Ker Gawl – Kahili ginger lily

Species Information

Family: Zingiberaceae

Initiation: On September 28, 2009, Al Tasker (Plant Protection and Quarantine's National Weeds Program Manager) forwarded an email chain about several invasive weeds (Tasker, 2009) to the Plant Epidemiology and Risk Analysis Laboratory (PERAL). Included in that list was *Hedychium gardnerianum*, which is an invasive weed in New Zealand that is no longer feasible to eradicate.

Foreign distribution: *Hedychium gardnerianum* is native to India, Nepal, Bangladesh, and Bhutan. It has been introduced into and is invasive in forest ecosystems in Australia, La Réunion, New Zealand, Portugal, Spain's Canary Islands, and South Africa (CABI, 2008). It is introduced and cultivated in the Cook Islands, Fiji, French Polynesia, the Federated States of Micronesia, and New Caledonia, and is introduced but not invasive in Mauritius, Rodriguez Island (PIER, 2011), Guadeloupe, Jamaica, Martinique, and the United Kingdom (CABI, 2008). It may be widespread in Ecuador, and could be present in more tropical areas than the literature indicates (CABI, 2008).

U.S. distribution and status: *Hedychium gardnerianum* was introduced into Hawaii as an ornamental in 1943 (CABI, 2008) and is now invasive there (PIER, 2011; CABI, 2008). An estimated $1 million is spent annually controlling this plant on an estimated 50,000 acres on the islands of Hawaii,

Kauai, Maui, and Oahu (CABI, 2008). It is sold at nurseries in the United States, and gardeners report cultivating it as an ornamental in Alabama, California, Florida, Hawaii, Mississippi, Texas, Virginia, and Washington (Dave's Garden, 2011).

WRA area[1]: Entire United States, including territories

1. *Hedychium gardnerianum* analysis

Establishment/Spread Potential

Hedychium gardnerianum is an aggressive, self-compatible, shade-tolerant plant (Csurhes and Hannan-Jones, 2008; CABI, 2008; Rambuda and Johnson, 2004) that forms dense colonies in both disturbed and undisturbed habitats (CABI, 2008; Environment Waikato Regional Council, 2011). Its seeds are spread by frugivorous birds (Medeiros, 2004; Corderio and Silva, 2003), while its rhizomes can break off and spread via water (CABI, 2008; BOP, 2012). Gardeners in New Zealand unintentionally disperse rhizomes as they dispose of yard waste (BOP, 2008). Through asexual reproduction, established plants can produce new generations annually (Corderio and Silva, 2003). The dense rhizome beds of *H. gardnerianum* [up to 1 meter thick (CABI, 2008)] can withstand fire (Smith, 1985), after which it can quickly dominate successional sites (Csurhes and Hannan-Jones, 2008). The congeneric species *H. flavescens* [New Zealand (BOP, 2008), La Réunion, Hawaii (CABI, 2008)], *H. coronarium* [Hawaii (CABI, 2008)], and *H. coccineum* [South Africa, Jamaica (Csurhes and Hannan-Jones, 2008)] are also weeds. The abundance of literature on *H. gardnerianum* and its establishment and spread gave a low uncertainty score for this risk element.

Risk score = 15 Uncertainty index = 0.08

Impact Potential

Hedychium gardnerianum is mainly an environmental pest; it reduces nitrogen, promotes erosion (CABI, 2008), inhibits stream flow (ISSG, 2010), reduces light availability (FAO, 2004), forms dense monotypic stands (Csurhes and Hannan-Jones, 2008), and displaces native plants (CABI, 2008). In Hawaii, *H. gardnerianum* threatens endangered species such as *Labordia tinfolia* var. *lanaiensis* and *Clermontia samuelii*. The Hawaiian islands have already spent close to $1 million trying to control it (CABI, 2008). Dense thickets of *H. gardnerianum* can block access to recreational areas (CABI, 2008). In New Zealand it is a noxious weed (CABI, 2008), and landowners in Bay of Plenty (BOP, 2008) and Waikato (Environment Waikato Regional Council, 2011) are required to control the plant on their properties. This species decimates forestry stands in the Azores (Csurhes and Hannan-Jones, 2008) and is a plantation weed in South Africa (CABI, 2008). We had an average uncertainty score for this risk element; more information on how the plant affects production systems would reduce our uncertainty.

Risk score = 3.7 Uncertainty index = 0.17

[1] "WRA area" is the area in relation to which the weed risk assessment is conducted [definition modified from that for "PRA area" (IPPC, 2012).

Geographic Potential Based on three climatic variables, we estimate that about 23 percent of the United States is suitable for the establishment of *H. gardnerianum* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *H. gardnerianum* represents the joint distribution of Plant Hardiness Zones 8-13, areas with 0-90 inches of annual precipitation, and the following Köppen-Geiger climate classes: tropical rainforest, tropical savanna, steppe, desert, humid subtropical, mediterranean, and marine west coast.

The area estimated likely represents a conservative estimate as it uses three climatic variables to estimate the area of the United States that is suitable for establishment of the species. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. Desert habitats are included in the estimated distribution due to the species' establishment in the Canary Islands. Despite this, *H. gardnerianum* is unlikely to establish in deserts and dry areas outside of moist microsites such as ravines and streamsides, so the predicted distribution likely overestimates the plant's potential range.

Entry Potential We did not assess the entry potential of *H. gardnerianum* because this species is already present in the United States (PIER, 2011).

Figure 1. Predicted distribution of *Hedychium gardnerianum* in the United States. Map insets for Alaska, Hawaii, and Puerto Rico are not to scale.

2. Results and Conclusion

Model Probabilities: P(Major Invader) = 83.6%
P(Minor Invader) = 15.8%
P(Non-Invader) = 0.6%

Risk Result = High Risk

Secondary Screening = Not Applicable

Figure 2. *Hedychium gardnerianum* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

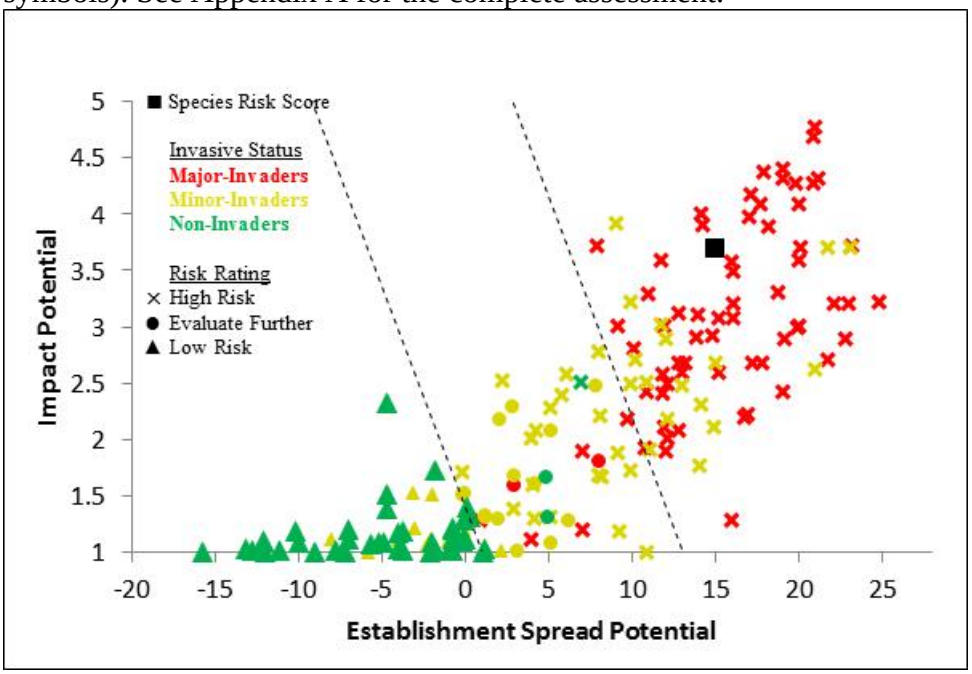
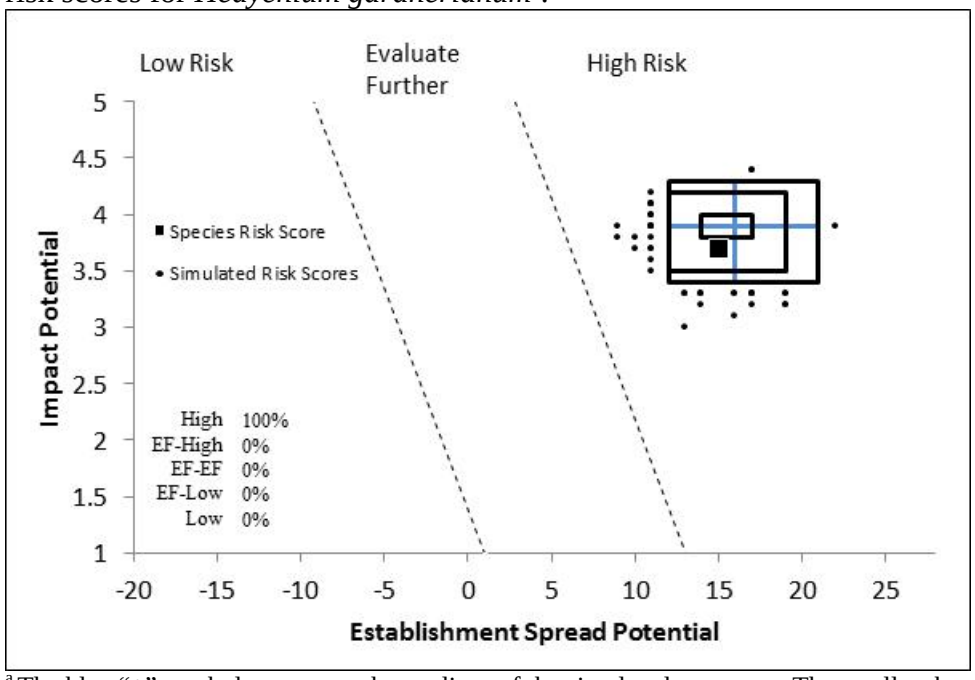


Figure 3. Monte Carlo simulation results (N=5,000) for uncertainty around the risk scores for *Hedychium gardnerianum*[a].



[a] The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *H. gardnerianum* is High Risk. This species invades natural ecosystems in a number of countries, including Australia, New Zealand, and South Africa. It could establish in about 23 percent of the United States (Fig. 1) and is already an invasive weed in Hawaii. The risk scores for *H. gardnerianum* fall well within the High Risk region (Fig. 2), due to its self-compatibility, the ease with which its propagules are spread, its ability to invade natural areas and outcompete native vegetation, and its impacts on forestry. The uncertainty for both risk elements was low to moderate due to the abundance of literature available on the species. In the Monte Carlo simulation, 100 percent of the simulations resulted in a determination of High Risk (Fig. 3). Additional information on certain risk factors would lower uncertainty further, but are very unlikely to affect the outcome of this analysis.

Hedychium gardnerianum can reproduce vegetatively (Corderio and Silva, 2003; Csurhes and Hannan-Jones, 2008) and hybridize in the wild with other *Hedychium* species (CABI, 2008). If planted as an ornamental in gardens and later disposed of as yard waste, it could become a problem in environmental areas, as has occurred in Australia, New Zealand, and Hawaii (CABI, 2008). *Hedychium gardnerianum* does not appear to be widely cultivated in the United States. As of November 2011, three U.S. vendors, in

Florida, Oregon, and Georgia, and several traders in Alabama, Mississippi, and Texas were advertising the plant or plant parts on a popular gardening website (Dave's Garden, 2011). Specialty mail-order nurseries located in North Carolina and Oregon list *H. gardnerianum* cultivars and cultivated hybrids for sale (Plant Delights Nursery, 2011; Rare Plant Research, 2012).

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Appendix A. Weed risk assessment for *Hedychium gardnerianum* Sheppard ex. Ker Gawl (Zingiberaceae). The following information was obtained from the species' risk assessment, which was conducted using Microsoft Excel. The information shown in this appendix was modified to fit on the page. The original Excel file, the full questions, and the guidance to answer the questions are available upon request.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 (Status/invasiveness outside its native range)	f - negl	5	"It is now listed as one of the most frequent and abundant plant invaders on the Azores and covers hundreds of hectares, completely dominating the understory in much of this area, and is expanding its range" (ISSG, 2004). "[I]t is naturalized in all the Azores islands, in Madeira Island, New Zealand, South Africa, Reunion Island and in the Hawaiian Archipelago," and is invasive in Hawaii, and the Azores (Corderio and Silva, 2003). Since it was first collected in the wild in northern New Zealand, it has spread to become a major weed (Williams et al., 2003). The alternative answers to this question for the Monte Carlo simulation are both "E."
ES-2 (Is the species highly domesticated)	n - negl	0	Some cultivars are available (e.g., 'Tara') (Csurhes and Hannan-Jones, 2008; CABI, 2008) and it is cultivated throughout the Pacific Islands (PIER, 2011), but there is no evidence that the plant is highly domesticated to reduce weediness.
ES-3 (Weedy congeners)	y - negl	1	Randall (2007) lists three congeners (*H. coccineum, H. coronarium, H. flavescens*) as Category 5 (declared noxious weeds). *Hedychium flavescens* must be controlled by land owners in the Bay of Plenty region as part of the BOP's plant pest management strategy (BOP, 2008; BOP, 2004) and is a weed in La Reunion. In Hawaii, *H. flavescens* and *H. coronarium* are weeds (CABI, 2008). "[*Hedychium*] *coccineum* is a weed in South Africa and Jamaica (Henderson 2001; Blood 2001; PIER 2004)" (Csurhes and Hannan-Jones, 2008). According to Weber (2003), *H. coronarium* and *H. flavescens* both "form dense thickets...impeding growth and regeneration of native plants." Csurhes and Hannan-Jones (2008) state that "[i]n South Africa, *H. gardnerianum*, together with *H. coccineum*, *H. coronarium* and *H. flavescens*, are declared pests, due to their propensity to invade forests, plantations, riverbanks and other moist, shaded sites." Smith (1985) ranks *H. flavescens* as one of the 86 most disruptive alien plants in Hawaii because of its capacity to form extensive monotypic stands.
ES-4 (Shade tolerant at some stage of its life cycle)	y - low	1	Csurhes and Hannan-Jones (2008) cited an observation by Esler (1988) that "colonies have been observed to die out following closure of the forest canopy above them" and assumed that this was because the light levels became too low. However, many sources (including Csurhes and Hannan-Jones, 2008) state that this is an aggressive plant that thrives in either bright light or dense shade (CABI, 2008), although growth may be suppressed (BOP, 2012) or seed production decreased (BOP, 2008) in the shade. It

Question ID	Answer - Uncertainty	Score	Notes (and references)
			"prefer[s] to grow in open, light-filled environments which are warm and moist, but will readily grow in semi and full shade beneath the forest canopy" (Auckland Regional Council, 1999). Grows in full shade in Hawaii (Minden et al., 2010). One gardening website lists its light requirements as "Full Sun, Sun to Partial Shade" (Dave's Garden, 2011). The die-out observed by Esler (1988) (cited in Csurhes and Hannan-Jones, 2008) was assumed to be caused by low light levels, but the weight of the evidence indicates that it at the very least tolerates shade.
ES-5 (Climbing or smothering growth form)	n - negl	0	It is an herb with erect stems (Weber, 2003).
ES-6 (Forms dense thickets)	y - negl	2	It "forms vast colonies" (BOP, 2012) and dense populations can block paths (CABI, 2008). It “is able to form dense thickets on undisturbed sites in the understorey of open and closed-canopy native rain forests and managed forests, as well as in open areas (forest margins, ravines or path sides)" (CABI, 2008). It "forms dense clumps in native forests" (Environment Waikato Regional Council, 2011).
ES-7 (Aquatic)	n - negl	0	It grows near water (CABI, 2008), but is not an aquatic plant.
ES-8 (Grass)	n - negl	0	This plant is in the family Zingiberaceae (CABI, 2008) and is therefore not a grass (Poaceae).
ES-9 (Nitrogen-fixing woody plant)	n - negl	0	The family is Zingiberaceae (CABI, 2008), which is not known to fix nitrogen (Martin and Dowd, 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Seed propagated (CABI, 2008; ISSG, 2010; PIER, 2011; Rambuda and Johnson, 2004).
ES-11 (Self-compatible or apomictic)	y - negl	1	This plant is inferred to be autogamous after a study showed it had 100 percent fruit set following both self-fertilization and bagging to exclude pollinators to test for autogamy. The study listed no previously published breeding system data (Rambuda and Johnson, 2004).
ES-12 (Requires special pollinators)	n - negl	0	Experiments where flowers were bagged (Rambuda and Johnson, 2004) showed that there was still seed set without pollinator assistance, confirming this species does not require specialized—or any—pollinators. The flower morphology suggests insect pollination, particularly by hovering insects with long tongues (moths, butterflies) (CABI, 2008).
ES-13 (Minimum generation time)	b - low	1	"Once established, a plant will spread radially by way of rhizomes, with new stems produced annually" (Csurhes and Hannan-Jones, 2008). "In general, only one or two corms were produced per rhizome, except at Carvão, where up to three or four corms could be produced per rhizome/year" (Corderio and Silva, 2003). It is a vegetatively propagated perennial (CABI, 2008). The alternative answers to this question for the Monte Carlo simulation are both “C.”
ES-14 (Prolific reproduction)	n - low	-1	Sources state that the seed production is high, but evidence puts the production rate well below the 5000 seeds/m2 needed for a "yes." "[I]t is estimated that the mean annual reproductive potential of a square meter area...for *Hedychium* is 2,024 seeds" (Medeiros, 2004). "In dense

Question ID	Answer - Uncertainty	Score	Notes (and references)
			infestations in Hawaii, seed production can be in the order of 2000 seeds/m2" (Csurhes and Hannan-Jones, 2008). "[O]ver 100 seeds may be produced per flower head" (ISSG, 2010). A "study of seed production and vegetative growth on São Miguel revealed that the number of seeds per spike ranged from 300 to 500 and concurred with the findings of Byrne (1992), which ranged from 20 to 600 depending on light conditions. ...[the species relies] on high annual seed production as a mechanism for efficient dispersal" (CABI, 2008).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - low	1	"The major source of this spread is by the illegal dumping of wild ginger rhizomes on roadsides or in bush" (BOP, 2008) by gardeners. U.S. gardeners are also likely to spread the rhizomes via yard waste after planting the species in their gardens.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	? - max	0	Unknown. CABI (2008) says that "Further spread is highly probable, owing to the risk of...accidental movement as a seed contaminant of crop seed and other agricultural produce." Yet it is not a weed in crop production systems (see Imp), and if it were, the fruit and seeds are conspicuous (CABI, 2008) and seem unlikely to go unnoticed. We are answering unknown until we can resolve CABI's statement.
ES-17 (Number of natural dispersal vectors)	2	0	Seed description for ES-17a-17e: The plant "produc[es] 1.5-2 cm long fleshy orange fruits: capsules persistent, oblong, 1.5 cm long, valves orange within each fruit contain small shiny red seeds included in a crimson arillus" (CABI, 2008). "Seeds are a bright scarlet red, measure 6mm by 4mm" (ISSG, 2010).
ES-17a (Wind dispersal)	n - negl		No evidence of wind dispersal. The seeds are conspicuous, fleshy, and red (CABI, 2008) and measure 6 mm by 4 mm (ISSG, 2010). The plant produces fleshy orange fruits with long valves (CABI, 2008), a morphological and coloration scheme more adapted to dispersal by frugivorous birds or rodents than by wind, and there is ample evidence that the seeds are bird-dispersed (BOP, 2008; Corderio and Silva, 2003; CABI, 2008; Medeiros, 2004).
ES-17b (Water dispersal)	y - low		Although this is not an aquatic species, it frequently occurs along streams (BOP, 2012). Short-distance dispersal by water is possible, as the rhizomes can break off and spread in water, or rain could disperse the seeds and corms (CABI, 2008; Corderio and Silva, 2003). It is "dispersed by water and soil disturbance" (BOP, 2012).
ES-17c (Bird dispersal)	y - negl		"Kahili ginger is also spread by birds, eating and dispersing the seeds away from the original infestations" (BOP, 2008). "Digestion of the seeds by birds does not impair *H. gardnerianum* seed germination (BYRNE 1992; CORDEIRO 2001)" (Corderio and Silva, 2003). "Seeds collected by birds may be eaten where they are found or transported" (CABI, 2008). The plant has "conspicuous and fleshy red seeds which are carried long distances by frugivorous birds" (CABI, 2008). Medeiros (2004) finds that seeds eaten and excreted by birds have a germination rate similar to that of non-ingested seeds.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17d (Animal external dispersal)	n - low		Frugivorous rats eat the seeds (CABI, 2008; Corderio and Silva, 2003), but there is no evidence that they transport the seeds externally. In the Hawaiian WRA for this species, the authors answered this question “no” because there is no way for the seed to attach to animals (University of Hawaii, 2005).
ES-17e (Animal internal dispersal)	n - high		Several sources state that the seeds are eaten by frugivorous rats (CABI, 2008; Corderio and Silva, 2003). Shiels (2011) hypothesizes that *H. garderanium* could be dispersed by black rats (*Rattus rattus*) in Hawaii, but does not provide direct evidence that rats disperse the seeds. Medeiros (2004) says that rodents of the genus *Rattus* in Hawaii actually reduce the seed production of kahili ginger, and any seeds passed through droppings are too masticated to germinate.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	n - negl	-1	The "seeds do not have dormancy... and only remain viable in the soil for a short period" (CABI, 2008). The "seeds do not have dormancy (CORDEIRO 2001), remaining viable in the soil for a relatively short period only. The invader might thus have a transitory seed bank, in which most of the seeds germinate or die in the period of a year" (Corderio and Silva, 2003).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	y - low	1	"[A]daptation to fire is unknown, but unless the fire is intense enough to harm the rhizomes, it will recover" (Smith, 1985). "Tolerates, or benefits from, cultivation, browsing pressure, mutilation, fire, etc." (CABI, 2008). "In Hawaii, *H. gardnerianum* can dominate early successional sites in some rainforest types after fire (Tunison et al. 2001)" (Csurhes and Hannan-Jones, 2008).
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	We found no evidence of this plant being resistant or having potential to become resistant to herbicides. Herbicidal treatments include Metsulfuron + Penetrant (BOP, 2012); "several herbicides" (CABI, 2008); and Escort, Roundup, and Amitrole (ISSG, 2010). It can spontaneously hybridize (CABI, 2008) with congeners, but they can be treated with herbicides as well (BOP, 2012). Not listed on weedscience.com as a plant known to be resistant to herbicides.
ES-21 (Number of cold hardiness zones suitable for its survival)	6	0	
ES-22 (Number of climate types suitable for its survival)	7	2	
ES-23 (Number of precipitation bands suitable for its survival)	9	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	n - low	0	There is no evidence of allelopathy, and this species is reasonably well studied.
Imp-G2 (Parasitic)	n - negl	0	No evidence that the species is parasitic. Zingiberaceae is not listed in references that cite families of parasitic plants (Heide-Jørgensen, 2008; Nickrent, 2011).

Question ID	Answer - Uncertainty	Score	Notes (and references)
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that affect other species)	y - negl	0.4	*Hedychium gardnerianum* has been found to reduce the amount of nitrogen available in rainforests (CABI, 2008; ISSG, 2010). It inhibits stream flow (ISSG, 2010) and promotes erosion (CABI, 2008). "The foliage of *Hedychium gardnerianum* absorbed 85–95 percent of the light that reached the understorey, thus reducing light available for seedling regrowth to less than one-sixth of the level in the absence of *H. gardnerianum*" (FAO, 2004).
Imp-N2 (Change community structure)	y - negl	0.2	*Hedychium gardnerianum* "changes structure and character of native rainforest vegetation" (PIF, 2010) and "alter[s]...both the function and structure of native forest" (Auckland Regional Council, 1999). It "produce[s] thick beds of rhizomes, forming a dense ground cover which prevents regeneration of other species...displaces lower tier plants of the native communities," and can create dense mats of rhizomes up to 1 meter thick (CABI, 2008; BOP, 2008). In the Azores, it "forms extensive, pure stands over entire hillsides" (Csurhes and Hannan-Jones, 2008).
Imp-N3 (Change community composition)	y - negl	0.2	*Hedychium gardnerianum* "smother[s] young native plants as well as preventing native seedling establishment" (BOP, 2008). "Once fully established it is extremely difficult for native seedlings to regenerate" (BOP, 2012). Changes plant community composition (Minden, 2011; Minden et al., 2010).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	y - negl	0.1	"[A] threat to *Labordia tinifolia* var. *lanaiensis* and *Clermontia samuelii* in Hawaii" (CABI, 2008). These two species, along with other species in these genera, are listed by the U.S. Fish and Wildlife Service (USFWS, 2012) as being endangered in Hawaii. "May permanently displace rare plants or cause serious losses to populations of uncommon plants or specialised communities" (BOP, 2012). Because *H. gardnerianum* changes community composition (BOP, 2008; BOP, 2012), it may prevent these native plants from establishing or regenerating.
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	y - negl	0.1	Globally outstanding ecoregions occur where the plant can potentially establish in the United States, and given that the plant can inhabit a diverse range, including coastal dune communities, coastland, riparian corridors, and wetlands (Csurhes and Hannan-Jones, 2008), it is likely that it would grow in these regions. Effects of its growth in these regions include preventing native seedlings from establishing or regenerating (BOP, 2008; BOP, 2012), altering the community structure by forming monotypic stands (Csurhes and Hannan-Jones, 2008) and displacing native plants (CABI, 2008), and reducing nitrogen (CABI, 2008) or light availability (FAO, 2004).
Imp-N6 (Weed status in natural systems)	c - negl	0.6	“A combined assessment of the estimated annual expenditure on kahili ginger control in the Hawaiian Islands of Kauai, Oahu, Maui and Hawaii come close to US $1 million, with approximately 50,000 acres estimated to be infested" (CABI, 2008). In the Azores, it is being controlled as part of the Azores bullfinch restoration project (ISSG,

Question ID	Answer - Uncertainty	Score	Notes (and references)
			2004). It is a weed in Kruger National Park, where control work is resisted within the community (McNeely, 2001). The alternative answers to this question for the Monte Carlo simulation are both “B.”
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	? - max	0	No direct evidence, but "often leads to erosion, with entire hillsides of *H. gardnerianum* disappearing at once. Erosion also downgrades water quality and causes siltation of rivers and harbours" (CABI, 2008). If this occurs in urban areas, we could answer "yes," but we found no evidence that it occurs in such areas.
Imp-A2 (Changes or limits recreational use of an area)	y - high	0.1	"Dense populations of *H. gardnerianum* can interfere with access to amenity areas, ravines sides, path sides, etc." (CABI, 2008).
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	n - low	0	Domestic gardens are listed as infestation sites (BOP, 2012), but no literature states that it negatively affects desirable plants and vegetation in gardens. In the United States, it is being sold as an ornamental garden plant (Dave's Garden, 2011).
Imp-A4 (Weed status in anthropogenic systems)	c - low	0.4	"Land occupiers are required to control wild ginger on their properties" in the Bay of Plenty (BOP, 2008), which is a popular leisure and recreation area. "All landowners/occupiers [in Waikato, New Zealand] are responsible for the control of wild ginger on their property and are required to work with Environment Waikato in areas where control programmes are in place" (Environment Waikato Regional Council, 2011). The alternative answers to this question for the Monte Carlo simulation are both “B.”
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	y - negl	0.4	"[H]as substantial impacts on forestry in the Azores, where it has caused the death of entire forestry plots of pine and *Acacia melanoxylon* trees" (Csurhes and Hannan-Jones, 2008). In the Azores, "Conteira (*H. gardnerianum*) causes problems for forestry operations due to the density levels...It has caused, and is still causing, significant problems within...plantation forests" (ISSG, 2004). Present in agricultural areas and pastures, but in pastures it is not likely to become a weed since livestock will eat it (Csurhes and Hannan-Jones, 2008).
Imp-P2 (Lowers commodity value)	? - max		"There are no records of direct impact on crops" (CABI, 2008). There is no information available indicating that *H. gardnerianum* lowers commodity value. It is possible that since it can decimate forestry plots in the Azores (Csurhes and Hannan-Jones, 2008) some sort of weed control is in effect that may raise crop production costs, but we did not find that information in the literature.
Imp-P3 (Is it likely to impact trade)	? - max		According to CABI (2008), crop seed and "other agricultural produce" provide a pathway, but this seems unlikely due to the morphology and size of the seed/fruit (see ES-16). Declared a weed of plantations in South Africa, prohibited as a noxious weed in New Zealand, and

Question ID	Answer - Uncertainty	Score	Notes (and references)
			species to be intercepted at ports in New Zealand and Hawaii (CABI, 2008).
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	No evidence.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - negl	0	No evidence it is toxic. Pigs presumably feed on rhizomes in Hawaii (Csurhes and Hannan-Jones, 2008). "It is highly palatable and non-poisonous to stock (NRC undated)" (Csurhes and Hannan-Jones, 2008).
Imp-P6 (Weed status in production systems)	b - mod	0.2	Impacts forestry plots in the Azores (Csurhes and Hannan-Jones, 2008; ISSG, 2004), but no evidence that it is being controlled there. Declared a weed of plantations in South Africa and prohibited as a noxious weed in New Zealand (CABI, 2008), but no evidence that it's being controlled in production systems. The alternative answers to this question for the Monte Carlo simulation are both "C."
GEOGRAPHIC POTENTIAL			Below, PS refers to Point Source data (i.e., geo-referenced data points) and OCC refers to occurs data (i.e., presence/absence in a region).
Plant cold hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	No evidence.
Geo-Z2 (Zone 2)	n - negl	N/A	No evidence.
Geo-Z3 (Zone 3)	n - negl	N/A	No evidence.
Geo-Z4 (Zone 4)	n - negl	N/A	No evidence.
Geo-Z5 (Zone 5)	n - mod	N/A	No firm evidence - native to Himalayas (to 1730 m elev) (Flora of Zimbabwe, 2012).
Geo-Z6 (Zone 6)	n - mod	N/A	No evidence.
Geo-Z7 (Zone 7)	n - low	N/A	PS: China (1 location) (GBIF, 2011); answering "no"--tropical--cold temps kill tops and "melt" rhizomes.
Geo-Z8 (Zone 8)	y - negl	N/A	PS: New Zealand (GBIF, 2011).
Geo-Z9 (Zone 9)	y - negl	N/A	PS: New Zealand (GBIF, 2011).
Geo-Z10 (Zone 10)	y - negl	N/A	PS: the United States (HI, FL), Australia (GBIF, 2011).
Geo-Z11 (Zone 11)	y - low	N/A	PS: Thailand (GBIF, 2011); OCC: Mexico (Tropicos, 2011), West Indies (NGRP, 2011).
Geo-Z12 (Zone 12)	y - low	N/A	OCC: Mexico (Tropicos, 2011), West Indies (NGRP, 2011).
Geo-Z13 (Zone 13)	y - negl	N/A	PS: the United States (HI) (GBIF, 2011).
Koppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	y - negl	N/A	PS: the United States (HI) (GBIF, 2011); OCC: Dominican Republic, Puerto Rico (NGRP, 2011).
Geo-C2 (Tropical savanna)	y - negl	N/A	PS: the United States (HI, FL), Thailand (GBIF, 2011).
Geo-C3 (Steppe)	y - mod	N/A	OCC: Dominican Republic (NGRP, 2011).
Geo-C4 (Desert)	y - low	N/A	OCC: Canary Islands (NGRP, 2011).
Geo-C5 (Mediterranean)	y - low	N/A	OCC: Azores (NGRP, 2011).
Geo-C6 (Humid subtropical)	y - negl	N/A	PS: Australia (GBIF, 2011).
Geo-C7 (Marine west coast)	y - negl	N/A	PS: China, Australia, New Zealand (GBIF, 2011).
Geo-C8 (Humid cont. warm sum.)	n - high	N/A	No evidence.

Question ID	Answer - Uncertainty	Score	Notes (and references)
Geo-C9 (Humid cont. cool sum.)	n - low	N/A	No evidence.
Geo-C10 (Subarctic)	n - negl	N/A	No evidence.
Geo-C11 (Tundra)	n - negl	N/A	No evidence.
Geo-C12 (Icecap)	n - negl	N/A	No evidence.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	y - high	N/A	OCC: Canary Islands (NGRP, 2011).
Geo-R2 (10-20 inches; 25-51 cm)	y - mod	N/A	OCC: Canary Islands (NGRP, 2011).
Geo-R3 (20-30 inches; 51-76 cm)	y - low	N/A	PS: New Zealand (GBIF, 2011).
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	PS: Australia (GBIF, 2011); OCC: the Azores (NGRP, 2011).
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	PS: Thailand, Australia (GBIF, 2011).
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	PS: the United States (FL), China, New Zealand (GBIF, 2011).
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	PS: the United States (HI), New Zealand (GBIF, 2011).
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	PS: New Zealand (GBIF, 2011).
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	PS: New Zealand (GBIF, 2011).
Geo-R10 (90-100 inches; 229-254 cm)	n - mod	N/A	No evidence.
Geo-R11 (100+ inches; 254+ cm)	n - low	N/A	No evidence.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	In Hawaii (CABI, 2008). Being sold and planted by gardeners in the contiguous United States (Dave's Garden, 2011).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	
Ent-4 (Entry as a contaminant)			
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	

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Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	