United States Department of Agriculture
Animal and Plant Health Inspection Service

Weed Risk Assessment for *S. inaequidens* DC. and *S. madagascariensis* Poir (Asteraceae)

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Introduction to Weed Risk Assessment

The Animal and Plant Health Inspection Service (APHIS) regulates noxious weeds under the authority of the Plant Protection Act of 2000. The Plant Protection Act defines a "Noxious Weed" 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." Under this act, APHIS lists those plants specifically designated as noxious weeds to enhance communication with the public and ensure transparency among all interest groups (7 CFR § 360, January 1, 2005). Under international agreements (IPPC, 1997), a country can only impose phytosanitary measures for regulated pests, including quarantine pests and regulated non-quarantine pests. A quarantine pest is defined by the IPPC as "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled." Under U.S. authority, federally listed noxious weeds may not be imported into the United States or moved interstate without a special permit.

APHIS uses qualitative risk assessments as a basis for most weed exclusion decisions and listing under federal noxious weed regulations (7 CFR § 360, January 1, 2005). In these qualitative assessments, risk is estimated in terms of High, Medium or Low, as opposed to numerical terms expressed as probabilities or frequencies. Plant Protection and Quarantine (PPQ) risk assessment procedures are harmonized with those of the North American Plant Protection Organization (NAPPO) and the International Plant Protection Convention (IPPC). Use of biological and phytosanitary terms (*e.g.*, introduction, quarantine pest) conforms with the *NAPPO Compendium of Phytosanitary Terms* (NAPPO, 1995) and the *Glossary of Phytosanitary Terms* ISPM No. 5 (IPPC, 2004).

Pest risk assessment is a component of pest risk analysis. ISPM No. 2 (IPPC, 1996) describes the three stages in pest risk analysis:

- Stage 1: Initiating the process (identifying a pest that may qualify as a quarantine pest, and/or pathways that may allow introduction or spread of a quarantine pest).
- Stage 2: Assessing the pest risk (determining which pests are quarantine pests, characterized in terms of likelihood of entry, establishment, spread and economic impact).
- Stage 3: Managing the pest risk (developing, evaluating, comparing and selecting options for managing the risk).

This document is a qualitative risk assessment of *Senecio inaequidens* DC. and *S. madagascariensis* Poir. (Asteraceae) that will be used to determine whether these species should be proposed for listing under federal noxious weed regulations (7 CFR § 360, January 1, 2005). The following risk assessment completes Stages 1 and 2 of the risk assessment process. APHIS considers eight steps in weed-initiated plant risk assessments (version 5.3, USDA, 2004):

Step 1. Document the initiating event(s) for the PRA (Stage 1).
Step 2. Identify and cite previous risk assessments (Stage 1).
Step 3. Establish weed identity (Stage 1).
Step 4. Verify quarantine pest status: geographic and regulatory criteria (Stage 2).
Step 5. Assess economic and environmental importance: consequences of introduction (Stage 2).
Step 6. Assess likelihood of introduction (Stage 2).
Step 7. Conclusion: determine pest risk potential (PRP) of weed (Stage 2).
Step 8. Document the PRA, cite references (Stage 2).

Stage 1 – Initiating the Pest Risk Assessment (PRA) Process

Step 1. Document the Initiating Event(s) for the PRA

This weed risk assessment (WRA) of *S. inaequidens* and *S. madagascariensis* represents APHIS-PPQ's continuous effort to identify potential noxious weeds that could be detrimental to U.S. agriculture, the environment, economy, and/or human health. This WRA was requested by Dr. Al Tasker, PPQ, Pest Detection and Management Programs (PDMP), Invasive Species and Pest Management (ISPM), National Noxious Weed Program Manager, who was concerned about the potential invasiveness of *S. inaequidens* after reading an EPPO alert on this species (EPPO, 2004).

Dr. Tasker originally requested that a WRA be done on *Senecio inaequidens* to evaluate the overall risk potential of this species with respect to the United States; however, a literature review revealed that *S. inaequidens* is part of a species complex that includes at least one other closely related, if not conspecific, taxon, *S. madagascariensis* (see Taxonomy section below). Based on recent evidence that these two taxa may be conspecific, the weed team at the Plant Epidemiology and Risk Analysis Laboratory (PERAL) decided it was prudent to consider *S. madagascariensis* in this risk assessment. The biology of these two species is considered side by side to help facilitate comparison; however, analysis of their risk potential was kept separate until an official final determination on their taxonomic status can be established.

Step 2. Identify and Cite Previous Risk Assessments

No previous risk assessments of *Senecio inaequidens* or *S. madagascariensis* have been conducted by APHIS PPQ.

Step 3. Establish Identity of Weed

<u>Identity and Taxonomy</u>

Senecio (Asteraceae) is a large genus with approximately 1,250 species distributed throughout the world (Mabberley, 1987). Because of its size, the large amount of genetic and phenotypic variation within and among the species, and the ease with which species hybridize, no worldwide phylogenetic treatment of the genus has been conducted (Pelser *et al.*, 2002). Consequently, there is no consensus about the identity of individual species and their placement among taxonomic groups (Pelser *et al.*, 2002). Because of the close resemblance of many *Senecio* species, specimens have frequently been misidentified, including specimens of *S. inaequidens* and *S. madagascariensis*. For example, in Argentina, *S. madagascariensis* has been misidentified as *S. burchellii* and *S. pellucidus*, while in Australia, it was previously considered *S. lautus* aff sp. *lanceolatus* (Sindel *et al.*, 1998).

Senecio inaequidens and *S. madagascariensis* are closely related taxa native to South Africa. Although difficult to distinguish, they can be distinguished based on life history, branching pattern and involucral bract length (Hilliard, 1977). Recent evidence from two independent studies, however, suggests these two taxa may represent one species. First, common garden experiments, where plants of both taxa are grown side by side, show that morphological characters used to distinguish the two taxa are highly variable and overlap (Lafuma, 2003). Cross fertilizations between them produce full seed sets with viable offspring (Lafuma, 2003). Secondly, molecular evidence using ITS1 sequence data shows there is no difference between *S. inaequidens* and *S. madagascariensis* in South Africa (Scott *et al.*, 1998). Unfortunately, a formal taxonomic study has not been conducted on this group of taxa to resolve this issue (Rogers, 2005). This weed risk assessment considers these two taxa, which are capable of interbreeding (Lafuma, 2003), as separate, but similar species.

<u>Senecio inaequidens</u>

Scientific Name: *Senecio inaequidens* DC.

Position: Dicotyledonae, Asterales, Asteraceae, *Senecio*

Synonyms: *S. harveianus* and *S. burchellii* (misapplied)

Varieties: NA

Common Names: Narrow-leaved ragwort; South African ragwort; Boton de oro (Sp.); Senecio amarillo (Sp.); Flor amarilla de Mar del Plata (Sp.); Senecioine sudafricano (It.); Schmalblattriges Greiskraut (Gr)

References: (Hilliard, 1977; Heger and Trepl, 2000; Pelser *et al.*, 2002; Rzedowski *et al.*, 2003; CABI, 2004)

<u>Senecio madagascariensis</u>

Scientific Name: *Senecio madagascariensis* Poiret

Position: Dicotyledonae, Asterales, Asteraceae, *Senecio*

Synonyms: *S. burchellii* auct. Non DC.; *S. incognitus* Cabrera (misapplied); *S. junodianus* O. Hoffm.; *S. ruderalis* Harvey. Possibly *S. litorosus* Fourcade.

Varieties: *S. madagascariensis* var. *madagascariensis*; *S. madagascariensis* var. *boutoni*.

Common Names: Fireweed; Variable groundsel

References: (Hilliard, 1977; Sindel *et al.*, 1998; Starr *et al.*, 2003; CABI, 2004)

<u>Description and Morphology</u>

Senecio inaequidens is a perennial herb that grows to one meter in height, with a highly branched stem which is woody at the base (Hilliard, 1977; Heger and Trepl, 2000). Although it is a perennial herb, it frequently behaves as an annual (Rzedowski *et al.*, 2003). Leaves can grow to 10 × 1 cm in moist, shady conditions, but they are much narrower in other environmental conditions (1-7 mm in width). Flowering heads (capitula) occur in panicles or corymbose cymes. The involucre is campanulate to subcylinder and is composed of about 20 linear-lanceolate bracts (3-6 mm in length). Capitula are lemon-yellow in color (approx. 25 mm in diameter) and have about 11-15 ligulate flowers (lamina 4-10 mm long) and about 100 disc flowers (3-5 mm long) (Rzedowski *et al.*, 2003). Plants in Europe bloom from early May to December (Heger and Trepl, 2000; CABI, 2004), whereas plants in Mexico primarily bloom between March and December, although some flowering individuals can be found year-round (Rzedowski *et al.*, 2003). Flowers are visited by many generalist pollinators, including Diptera, Hymenoptera, and Lepidoptera. Achenes are subcylindrical, from 1.5 to 2.5 mm long, and hispid between the ribs (Hilliard, 1977).

Senecio madagascariensis is an erect, branched perennial herb that can grow to 60 cm tall; stems can sometimes be decumbent (Fig. 1). Stems are glabrous or sparsely hairy, simple below and often branching above (Hilliard, 1977). Leaves (up to 12 × 2.5 cm) are alternate and variable in morphology, usually linear-lanceolate. Leaf margins vary from toothed (especially on lower leaves), to entire, to pinnately lobed (especially on upper leaves). Leaf bases are sometimes auriculate. Flowers occur in flower heads (1-2 cm wide capitula, typical of the Asteraceae) with both ray and disc flowers (approx. 100-120 total). The corolla length of ray flowers, which number 12-13 is approximately 8-14 mm. Ray and disc florets are yellow in color. An individual plant can produce 2-200 capitula. Fruits are ribbed achenes that range from 1.4-2.75 mm long and have short bristles along their surface (Reed, 1977). A pappus (6 mm long) is attached to the seeds and functions in wind dispersal. Roots can extend 10-20 cm deep (Sindel *et al.*, 1998; Starr *et al.*, 2003). In Australia, *S. madagascariensis* is an obligate outcrosser (Sindel *et al.*, 1998).

<u>Key Characters for Identification</u>
A description of key characteristics that distinguish *S. inaequidens* and *S. madagascariensis* from each other and other *Senecio* species is beyond the scope of this weed risk assessment, given the taxonomic challenges to differentiate species within the genus. Overall, these two species belong to a group of species in South Africa which are difficult to distinguish, and include *S. burchellii, S. skirrhodon,* and *S. harveianus*. According to Hilliard's work on the "Compositae of Natal", *S. inaequidens* can be distinguished from *S. madagascariensis* based on the following characteristics: 1). *Senecio inaequidens* is typically a perennial herb with stems branching from the base, while *S. madagascariensis* is an annual with stems branching from above the base of the stem (Hilliard, 1977). 2). The involucral bracts of *S. inaequidens* are typically 5-6 mm long, though some are four mm in length; the bracts of *S. madagascariensis* are typically 4-5 mm long, and some are 6 mm long. 3). Furthermore, Hilliard states that *S. inaequidens* is a montane species occurring between 1400 and 2850 meters above sea level, while *S. madagascariensis* occurs below 1400 meters in elevation.

In Australia, it was only recently that *S. madagascariensis* was teased apart from *S. lautus* (now called *S. pinnatifolius*; Radford *et al.*, 2004). They can now be distinguished by examining the number of involucral bracts, achene morphology, chromosome number, and habitat segregation (Scott *et al.*, 1998; Radford and Cousens, 2000).

Current Distribution
Senecio inaequidens is native to the Transvaal and Natal provinces of South Africa in grassland habitats of the highveld (1400-2800 m) (Sans *et al.*, 2004). It also occurs in Botswana, Lesotho, Mozambique, Namibia, and Swaziland (EPPO, 2004), but it is unclear if it is native to those areas (CABI, 2004). Because it is a weedy species, even in its native habitat (Urban, 2005), it is possible that it has spread to other areas in southern Africa in recent years. *Senecio inaequidens* was first recorded outside its native range in Germany, in 1889 (EPPO, 2004). Due to other independent introductions and subsequent spread, it is currently present in many European countries, including Andorra, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Northern Ireland, Norway, Poland, Spain, Sweden, Switzerland and the United Kingdom (Bornkamm, 2002; Lafuma *et al.*, 2003; EPPO, 2004; FNI, 2004). According to CABI, there is an 'unreliable' record of *S. inaequidens* in Colombia (CABI, 2004). *S. inaequidens* is also present in Mexico and may have been there for 50 years in one locality (Rzedowski *et al.*, 2003; Villaseñor and Espinosa-Garcia, 2004).

Senecio madagascariensis is native to southern Africa in the countries of South Africa, Madagascar, Mozambique, South Africa, and Swaziland (CABI, 2004). It has recently naturalized in the highlands of Kenya at around 2,800 meters elevation (Sindel *et al.*, 1998). It is present in southeastern Australia in the states of New South Wales, Victoria and Queensland where it is a noxious weed (Radford *et al.*, 1995). The genotypes invading Australia originated in South Africa and not in Madagascar (Scott *et al.*, 1998; Sindel *et al.*, 1998). *Senecio madagascariensis* has also naturalized in Argentina. When first detected in Argentina in the early 1940's, it was misidentified as *S. incognitos*; later, it was misidentified again as *S. burchellii* (Sindel *et al.*, 1998). *Senecio madagascariensis* has recently been reported in Japan (Kinoshita *et al.*, 1989 in Rzedowski *et al.*, 2003). One author who considers *S. madagascariensis* and *S. inaequidens* to be the same species, described using DNA samples of *S. madagascariensis* from Mexico (Lafuma *et al.*, 2003).

Climatic and Ecological Tolerance
Although it prefers well-drained, disturbed habitats, *Senecio inaequidens* is a pioneer species that grows in a wide range of habitats (EPPO, 2004). It can occur as high as 2,700 meters in elevation and grows along roads, railways, river banks, wastelands, forest clearings, croplands, alpine fields, mountain slopes, vineyards, grasslands, heathlands, wetlands, tree plantations, pastures and fallow fields, and areas disturbed by fire (Bornkamm, 2002; Roca, 2003; Rzedowski *et al.*, 2003; EPPO, 2004). It can withstand winter temperatures as low as -15˚C (corresponding to USDA Plant Hardiness Zone 7) and it tolerates hot, dry summers, characteristic of Mediterranean regions (Ernst, 1998). In Mexico, *S. inaequidens* grows in regions with only 700 to 800 mm of rainfall per year (mostly during the summer) (Rzedowski *et al.*, 2003). Overall, *S. inaequidens* appears to invade three types of climatic regions: subtropical maritime habitats (*e.g.*, South Africa); temperate humid environments (*e.g.*, central Europe); and tropical montane habitats (*e.g.*, Mexico) (Rzedowski *et al.*, 2003).

Senecio madagascariensis is a weedy species that grows in disturbed sites, contour banks, pastures, grasslands, and areas recently burned (Radford *et al.*, 1995; Sindel *et al.*, 1998). It has been described as occurring in two types of climatic regions: high altitude equatorial habitats (*e.g.*, Colombia and Kenya), and subtropical maritime habitats that receive 500 to 1,000 mm of rainfall per year (*e.g.,* southeast Australia) (Sindel *et al.*, 1998). Mean annual temperatures at Australian sites range from 12.3˚C to 20.9˚C and correspond to USDA Plant Hardiness Zones 8-10 (Dawson, 2005). In Australia, seedlings are reported to be frost sensitive (Sindel *et al.*, 1998). *Senecio madagascariensis* can also occur in high elevation sites (*e.g.*, 1,500 meters in Africa, 2,800 meters in Colombia). A study that examined the population density of *S. madagascariensis* in relation to the abundance of pasture species showed that relatively little variation in *S. madagascariensis* density is associated with the abundance of other species, suggesting other factors are important in determining its distribution (Radford *et al.*, 1995).

<u>Weed Biology</u>

Weediness of Senecio inaequidens. *Senecio inaequidens* is an invasive exotic weed in a variety of habitats in 17 European countries (Bornkamm, 2002; Lafuma *et al.*, 2003; EPPO, 2004; FNI, 2004) where it is considered to be a weed of "considerable significance" (EPPO, 2004; Sans *et al.*, 2004). It is also present in Mexico where it invades disturbed sites and roadway edges (Rzedowski *et al.*, 2003; Villaseñor and Espinosa-Garcia, 2004). In South Africa, where *S. inaequidens* is native, it is considered a roadside weed (Hilliard, 1977; Heger and Trepl, 2000; Urban, 2005).

Although *S. inaequidens* primarily invades anthropogenically disturbed habitats (Heger and Trepl, 2000; Roca, 2003; EPPO, 2004), it can also colonize natural habitats, such as rocky sites and river edges that are frequently disturbed or offer little interspecific competition from other species (Heger and Trepl, 2000; Rzedowski *et al.*, 2003; CABI, 2004). Seed propagule pressure created by dense stands has promoted the invasion of *S. inaequidens* into more unusual habitats, such as along the edges of buildings and lawns (Heger and Trepl, 2000), and into areas not necessarily associated with human disturbance (Bohmer, 2001 in Rzedowski *et al.*, 2003). It has also appeared in flower pots, flat roofs, highway medians, *etc*.

Senecio inaequidens was first introduced into Europe as early as 1889 via the wool industry (summarized in Lopez-Garcia and Maillet, 2005). It first became established near a few wool importation and processing facilities, but later spread along roads and railways to other areas (CABI, 2004). Although, present in Europe for over a century, it has been considered a weedy species only since the 1970's. It is suspected that during this period (the lag phase), it was adapting to a North Atlantic climate of cold, wet winters (Ernst, 1998). Indeed, phenological observations suggest that European populations have been evolving over time. Initially, the flowering period for *S. inaequidens* in Europe was August to October (1939-1977), but since then, it has extended in both directions (1990's: May to December), particularly towards earlier flowering (Ernst, 1998). This shift has allowed *S. inaequidens* to develop two generations per year in some areas.

On a local scale, the invasion of *S. inaequidens* in Europe is characterized by a lag phase of several years to several decades. Its invasion has been classified into three stages: initial colonization characterized by a few scattered individuals; an establishment phase where immigration is no longer necessary to sustain a population; and an explosive phase where the population becomes a source from which further invasion begins (Heger and Trepl, 2000).

Senecio inaequidens does very well in disturbed habitats (Ernst, 1998). It also performs well in grassland habitats that are periodically grazed because it produces pyrrolizidine alkaloids that deter herbivores. In an experimental study, Scherber *et al.* (2003) showed that plants that are grazed by rabbits once, become unpalatable thereafter, and deter future grazing; thus, under grazing conditions, herbivores indirectly promote the continued invasion of *S. inaequidens* into fields by eliminating competing vegetation. Other factors that may also contribute to the demographic success of this species include a relatively short pre-reproductive period and adaptability to varying environmental conditions (Sans *et al.*, 2004).

Weediness of Senecio madagascariensis. *Senecio madagascariensis*, like *S. inaequidens,* is a weed in its native habitat in South Africa (Urban, 2005). It is also considered a serious weed in Australia and Argentina where it causes considerable agricultural damage (Radford and Cousens, 2000; Lopez-Garcia and Maillet, 2005). *Senecio madagascariensis* has naturalized in the highlands of Kenya (2600m), in croplands and grasslands of Argentina, in improved pastures and ruderal habitats in Australia, and along roadsides (2800 meters) near Bogotá Colombia (Sindel *et al.*, 1998; Radford and Cousens, 2000). The earliest record of *S. madagascariensis* in Australia is in 1918, when it was probably introduced in ballast water (Sindel *et al.*, 1998). Currently, it is distributed throughout coastal southeastern Australia and in some isolated localities further inland around watering holes. *Senecio madagascariensis* has the potential to invade parts of northern Australia that annually receive at least 400 mm of rain. It continues to spread throughout Australia through cattle feed and forage that comes from contaminated fields (Sindel *et al.*, 1998).

Senecio madagascariensis is a state noxious weed in Hawaii (Skinner *et al.*, 2005), where it was first reported in the early 1980's on the island of Hawaii (Starr *et al.*, 2003). Since then it has been documented on Kauai, Maui, Oahu, and Kaahoolawe, invading pastures, yards, roadsides, natural areas, abandoned fields, and newly developed lots from sea level to as high as 7,000 ft. in elevation (Fig. 2). The infestation on Kauai is contained and requires constant surveys to eliminate remnant *S. madagascariensis* seeds in the area. This infestation was due to the use of groundcover seed that was contaminated with *S. madagascariensis* seeds (Starr *et al.*, 2003).

The establishment and performance of *S. madagascariensis* seems to be positively influenced by drought in pastures, as drought inhibits the growth of competitors (Sindel *et al.*, 1998). In its native habitat in Natal (South Africa), it usually occurs in disturbed habitats. Following a three year drought in Australia, *S. madagascariensis* appeared in natural communities and pastures (Sindel *et al.*, 1998); the following year, when the drought ended, it did not reappear. Overgrazing of pastures, or any other factors that reduce the competitiveness of pasture species, promotes the invasion of *S. madagascariensis* (Sindel *et al.*, 1998). Due to its economic and environmental impacts, this species is being actively controlled in Hawaii (Starr *et al.*, 2003).

Stage 2 – Assessing Pest Risk

Step 4. Verify Quarantine Pest Status: Regulatory & Geographic Criteria

The IPPC defines a quarantine pest as "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (IPPC, 2002). Thus, pest satisfying this definition, must meet geographic and regulatory criteria, respectively. According to the USDA's National Plant Database, *S. inaequidens* is not present in the U.S., while *S. madagascariensis* is present in only Hawaii (USDA-NRCS, 2005), where it is a state listed noxious weed (Skinner *et al.*, 2005) and not widely distributed among all islands in the Hawaii. Where it does occur, measures are implemented to eradicate or control populations (Arakaki, 2005b). Neither species is on the federal noxious weed list (7 CFR § 360, January 1, 2005).

Step 5. Assess Economic and Environmental Importance: Consequences of Introduction

Potential consequences of weed introduction are rated using four risk elements: habitat suitability, economic impact, spread/dispersal potential, and environmental impacts. These risk elements are used to assess a plant's ability to establish, spread, and cause environmental and economic damage. For each risk element, plants are assigned a risk rating of Negligible (0 points), Low (1 point), Medium (2 points), or High (3 points) (USDA, 2004). A Cumulative Risk Rating is then calculated by summing all risk element values. The values determined for the Consequences of Introduction are summarized in Table 1. Associated with each risk rating is a certainty rating that describes the risk assessor's overall confidence in the risk rating. There are five possible levels of certainty (very low, low, medium, high, and very high). *Senecio inaequidens* and *S. madagascariensis* were evaluated separately, but in tandem, to facilitate comparison.

Risk Element #1: Habitat Suitability

Explanation	Rating
In most of the United States (in four or more plant hardiness zones).	High (3)
In approximately one third to two thirds of the U.S. (two or three plant hardiness zones).	Med. (2)
In approximately one third or less of the United States (at most a single plant hardiness zone).	Low (1)
No potential to survive and become established.	Negl. (0)

S. inaequidens

Rationale for Rating:
Senecio inaequidens occurs in several countries in southeastern Africa, including South Africa, where its geographic distribution (Lafuma *et al.*, 2003) corresponds to USDA Plant Hardiness Zones 8-12 (Page and Olds, 2001). Its geographic distribution throughout southern and central Europe corresponds to USDA Zones 6-9 (Page and Olds, 2001). The literature reports that *S. inaequidens* is tolerant of winter temperatures as low as -15˚C (Ernst, 1998), which corresponds to Zone 7; thus, according to these data, *S. inaequidens* would be able to survive in over four Plant Hardiness Zones in the United States.

Certainty of Rating: Very High
Risk Rating: High

<u>S. madagascariensis</u> **Rationale for Rating:** *Senecio madagascariensis* occurs in several countries in southeastern Africa, and is distributed in humid, maritime, subtropical climates (CABI, 2004). Its distribution in Africa and southeastern Australia corresponds to USDA Plant Hardiness Zones 9-12 (Page and Olds, 2001; Dawson, 2005). *Senecio madagascariensis* is already present in Hawaii, which includes Hardiness Zones 9-11; thus, *S. madagascariensis* would be able to survive in three U.S. Plant Hardiness Zones. **Certainty of Rating:** Very High **Risk Rating:** Medium

<u>Risk Element #2: Spread Potential after Establishment, Dispersal Potential:</u>
The capacity of a plant species to spread across a landscape depends on two biological processes: population growth, which reflects the species' ability to grow rapidly and reproduce; and dispersal potential, which determines the distance that plant propagules are dispersed away from the parent plant into the surrounding landscape (Shigesada and Kawasaki, 1997; Neubert and Caswell, 2000). These biological processes are, in turn, influenced by a variety of other factors and processes. For example, population growth is influenced by herbivore damage, interspecific competition, and many species traits. A rating for this risk element considers many of these factors, including the ones listed below (USDA, 2004). Those traits possessed by *S. inaequidens* and *S. madagascariensis* were indicated with an **I** or **M**, respectively.

- Consistent and prolific seed production (**I**, **M**).
- Rapid growth to reproductive maturity (**I**, **M**).
- High germination rate under a wide range of conditions (**I, M**).
- Ability to suppress the growth of other plants by releasing a chemical inhibitor.
- Ability to persist as dormant long-lived propagules or underground parts, such as rhizomes, tubers, turions or stolons.
- Seed dormancy (**I**, **M**).
- Stress tolerance, including the ability to resist herbicides (**I, M**).
- Ability to colonize a wide variety of habitats (**I**).
- Lack of natural control agents or relatively tolerant of herbivore damage (**I**, **M**).
- Well-developed storage tissue (for example, tap root).
- Dispersal by wind, water, machinery, animals and/or humans (**I**, **M**).
- Species is invasive elsewhere (**I**, **M**).
- Congeners are invasive elsewhere (**I**, **M**).

Explanation	**Rating**
Weed has the potential for rapid natural spread throughout its potential range in the PRA area (*e.g.*, high reproductive potential ***AND*** highly mobile propagules).	High (3)
Weed has the potential for natural spread throughout a physiographic region of the PRA within a year (*e.g.*, it has either high reproductive potential ***OR*** highly mobile propagules).	Med. (2)
Weed has the potential for natural spread locally in the PRA area within a year (some reproductive potential and/or some mobility of propagules).	Low (1)
Weed has no potential for natural spread in the PRA area.	Negl. (0)

S. inaequidens

Rationale for Rating:

Reproductive potential:

Senecio inaequidens is a polycarpic (flowering multiple times) perennial that can produce flowers in its first year. Reproduction is primarily sexual in *S. inaequidens*, although stems may root if they touch the ground (CABI, 2004). A single plant can produce up to 10,000 seeds through an extended flowering period (Lopez-Garcia and Maillet, 2005). It is effectively self-incompatible; however, the degree of self-incompatibility varies and it can produce some selfed progeny through geitonogamy (cross-pollination within a plant but between different flowers) (Lopez-Garcia and Maillet, 2005).

Senecio inaequidens displays three different kinds of seed dormancy, increasing its chances for encountering favorable germination conditions across time. Seeds maturing in July have a dormancy period of only a few days and will readily germinate, whereas, seeds produced in December have a strong dormancy period (Ernst, 1998). Buried seeds can remain viable for at least one year, but seeds at the soil surface remain viable for only six months (Lopez-Garcia and Maillet, 2005). Seed germination, which is favored by compacted soils, is rapid and takes place throughout the year (EPPO, 2004).

Contributing to its overall competitive ability, *S. inaequidens* shows relatively high growth rates under a range of nutrient levels. Higher nitrogen availability stimulates faster growth and larger leaves (Lopez-Garcia and Maillet, 2005), both of which contribute to its ability to compete for light. Although *S. inaequidens* is a perennial, it can behave as an annual, proceeding from germination to flowering in 80 days, under certain conditions (Ernst, 1998).

Dispersal Potential:

Senecio inaequidens produces small, wind-dispersed seeds that are readily picked up by air currents. Although there is evidence that it can disperse up to 250 km away, long-distance wind dispersal is, or at least has been, a rare event (Ernst, 1998). Studies of wind dispersal in other plumed seeds of the Asteraceae document most dispersal distances within 30 meters, but in some rare events, greater dispersal distances are possible (e.g., 1%-2% of dispersed seeds) (Bergelson *et al.*, 1993; Skarpaas *et al.*, 2004). The distance a wind-dispersed seed migrates from its parent is a function of the height of seed release, terminal velocity, wind speed, tree canopy structure, forest structure, air turbulence, and climate (Hensen and Muller, 1997; Lanner, 1998).

Overall, *S. inaequidens* has a high dispersal potential. After establishing primary populations throughout Europe, it rapidly expanded its distribution. Anthropogenic mediated dispersal is primarily responsible for its spread, but it has also colonized new areas through wind and water dispersal (Ernst, 1998). *S. inaequidens* spreads well along railways and highways. Turbulent air currents associated with these corridors promotes the long distance dispersal of this plant (Heger and Trepl, 2000). Despite the rarity of long distance dispersal events, the numerous instances of populations establishing along railways demonstrates the importance of these chance events (Ernst, 1998). Seeds of *S. inaequidens* may also be dispersed over long distances by adhering to vehicles and trains (Heger and Trepl, 2000).

Certainty of Rating: Very High
Risk Rating: High

S. madagascariensis

Rationale for Rating:
Reproductive potential:
Senecio madagascariensis is a polycarpic perennial that can produce flowers in its first year. Plants begin flowering six to ten weeks after germinating (Sindel *et al.*, 1998). Because it produces 55 to 120 seeds per capitulum, and up to 230 capitula per plant, it can easily produce over 10,000 seeds per plant (Sindel *et al.*, 1998).

Senecio madagascariensis produces three kinds of achenes (seeds) - dark brown, light brown and green - which vary in seed dormancy. Dark brown and green seeds are produced toward the periphery of the capitula. Light brown seeds are internal and have little dormancy. Dark brown seeds have a much longer innate dormancy period, whereas green seeds have an intermediate dormancy period (Sindel *et al.*, 1998). At dispersal, the majority of the seeds are viable and up to 90% can germinate under controlled conditions. Seeds germinate well between 15˚C and 27˚C, but beyond that, germination sharply falls (Sindel *et al.*, 1998). In Australia, *S. madagascariensis* typically does not germinate in the middle of summer or winter. Seeds may remain viable in the soil for up to 10 years (Sindel *et al.*, 1998).

Senecio madagascariensis is highly invasive in Australia, where it has spread rapidly around coastal regions (Sindel *et al.*, 1998). Dense infestations of 5,000 plants per square meter have been recorded. Active growth during the winter gives it a competitive advantage over other species that do not grow during this time (Sindel *et al.*, 1998).

Dispersal Potential:
Senecio madagascariensis produces small, wind-dispersed seeds (2.75 mm by 0.6 mm (Reed, 1977), most of which are dispersed within five meters of the parent plant (Sindel *et al.*, 1998). Sindel *et al*. (1998) report this species may be more readily dispersed by wind than any other *Senecio* species, perhaps because its achenes weigh less (135 µg vs. 686 µg in *S.*

lautus from Australia). Studies of wind dispersal in other plumed seeds of the Asteraceae family document most dispersal distances within 30 meters, but, greater dispersal distances are possible (*e.g*., 1%-2% of dispersed seeds) (Bergelson *et al*., 1993; Skarpaas, 2004 #1803). The distance a wind-dispersed seed migrates from its parent is a function of the height of seed release, terminal velocity, wind speed, tree canopy structure, forest structure, air turbulence and climate (Hensen and Muller, 1997; Lanner, 1998). Although most wind-dispersed seeds will fall underneath or near their parent tree, some, if caught in an updraft, can be transported relatively far from their parent tree, *i.e*., at least several hundred meters (Kot *et al*., 1996; Lanner, 1998; Ledgard, 2001).

Because *S. madagascariensis* produces large quantities of seed, seeds can readily contaminate many surfaces and objects, and thus, be secondarily dispersed. It can be dispersed in hay, hydromulch, and grain products, as well as on animals, humans and vehicles (Sindel *et al*., 1998; Starr *et al*., 2003). It is believed that *S. madagascariensis* was introduced to Australia in ballast water (Sindel *et al*., 1998). In the early 1980's, it was introduced to the Kohala area of Hawaii in contaminated hydromulch (Arakaki, 2005b; Starr, 2005). Given these data and ease with which it has spread in Australia, it has a high dispersal potential.

Certainty of Rating: Very High
Risk Rating: High

Risk Element #3: Economic Impact Rating:

The variety of economic impacts caused by introduced weeds can be divided into three primary categories. The following factors were considered in this assessment. Those that applied to *S. inaequidens* and *S. madagascariensis* were indicated with an **I** or **M**, respectively.

- Reduced crop yield (*e.g.*, by parasitism, competition, or by harboring other pests) (**M**).
- Lower commodity value (*e.g.*, by increasing costs of production, lowering market price, or a combination, or if not an agricultural weed, by increasing costs of control) (**I, M**)
- Loss of markets (foreign or domestic) due to the presence of a new quarantine pest) (**M**).

Explanation	**Rating**
Weed causes all three of the above impacts, or causes any two impacts over a wide range (over 5 types) of economic plants, plant products, or animals.	High (3)
Weed causes any two of the above impacts, or causes any one impact to a wide range (over 5 types) of economic plants, plant products, or animals.	Med. (2)
Weed causes any one of the above impacts.	Low (1)
Weed causes none of the above impacts.	Negl. (0)

S. inaequidens

Rationale for Rating:
Not much information is available on the economic impact of *Senecio inaequidens*. Currently, CABI and EPPO report its impact is minimal, but that more studies need to be done (CABI, 2004; EPPO, 2004). *Senecio inaequidens* is a weed in managed forests, pastures and vineyards (Heger, 2000 #1789), but its importance and impact are unknown. (CABI, 2004). Although it has the capacity to invade many other different habitats, in Europe and Mexico, it is primarily an invader of ruderal and disturbed sites, such as railways and highways, (Bornkamm, 2002; Lafuma *et al.*, 2003; EPPO, 2004; FNI, 2004). *Senecio inaequidens* has shown a strong capacity to evolve and adapt to new surroundings (Ernst, 1998); thus, it is possible that it could have a stronger economic impact in the future (CABI, 2004). Currently, it is causing an economic loss in Europe due to control costs (Heger and Trepl, 2000; Bornkamm, 2002; CABI, 2004), however, this amount has not been specified.

Senecio inaequidens produces toxic pyrrolizidine alkaloids (Macel and Vrieling, 2003; CABI, 2004), which would harm grazing animals, such as sheep, cattle, horses, goats, *etc* if ingested. It may be problematic if it spreads into grain fields (Altaee and Mahmood, 1998). In Africa, where it is a weed in croplands and pastures, its alkaloids have been found in milk and bread and may have resulted in some lethal, human poisoning (Heger and Trepl, 2000). It is unknown if grain-processing technologies in the U.S. would be able to remove *Senecio* seed contaminants.

Even though data regarding the economic impact of *S. inaequidens* is limited, it is clear that its introduction would stimulate control efforts, as it has in Europe. Overall, the Economic Impact Rating is deemed to be Medium. Future studies and data may show that it should be High.

Certainty of Rating: Medium
Risk Rating: Medium

S. madagascariensis

Rationale for Rating:
Invasion by *S. madagascariensis* in the U.S. would primarily impact the dairy and cattle industry because it contains pyrrolizidine alkaloids that are toxic to livestock (Sindel *et al.*, 1998). *S. madagascariensis* deters cattle grazing, retards growth and development if eaten, and in some acute cases it causes mortality (Radford *et al.*, 1995). Although horses and cattle may not eat it because of its bitter taste, young plants growing intermixed with pasture species may be inadvertently eaten by cattle (Sindel *et al.*, 1998). Because *S. madagascariensis* is toxic, whether green or dry, fodder contaminated with it will also poison cattle (Starr *et al.*, 2003). A 1995 Australian study estimated that *S. madagascariensis* cost the Australian dairy industry AU $10 million per year (Radford *et al.*, 1995). Abundance and impact of *S. madagascariensis* in Australia has stimulated interest in the biological control of this pest (Radford *et al.*, 1995).

Besides contaminating fields and pastures grown for fodder, *S. madagascariensis* also

competes with pasture species for limiting resources. Densities of 40 plants per square meter reduced pasture growth by 70% in one study (Sindel *et al.*, 1998). In Hawaii, *S. madagascariensis* is well established and rapidly spreading in pastures, disturbed sites, and natural areas (Starr *et al.*, 2003). Various control strategies have been developed or are being pursued to slow, stop and prevent its spread (Motooka *et al.*, 2004; Arakaki, 2005b). Finally, if *S. madagascariensis* were to become established in the U.S., the U.S. may experience a loss in some grain, cattle, hay and dairy markets (domestic and foreign) due to toxic alkaloid contamination. **Certainty of Rating:** Very High **Risk Rating:** High

<u>Risk Element #4: Environmental Impact:</u>
Introduced weeds can cause a variety of environmental impacts. A rating under this element considers whether the introduced species could have the following impacts. Those that applied to *S. inaequidens* and *S. madagascariensis* were indicated with an **I** or **M**, respectively.

- Cause impacts on ecosystem processes (alteration of hydrology, sedimentation rates, a fire regime, nutrient regimes, *etc*.). (**I**).
- Cause impacts on natural community composition (*e.g.*, reduces biodiversity, affects native populations). (**I, M**).
- Cause impacts on community structure (*e.g.*, changes the density of a layer, covers the canopy, eliminates or creates a layer).
- Have impacts on human health, such as allergies or changes in air or water quality. (**I, M**).
- Have sociological impacts on recreation patterns and aesthetic or property values. (**M**).
- Introduction of the weed would stimulate control programs including toxic chemical pesticides. (**I, M**).

<u>Explanation</u>	**<u>Rating</u>**
Three or more of the above (Potential to cause major damage to the environment with significant losses to plant ecosystems and subsequent physical environmental degradation).	High (3)
Two of the above (Potential to cause moderate impact on the environment with obvious change in the ecological balance, affecting several attributes of the ecosystem, as well as moderate recreation or aesthetic impacts).	Med. (2)
One of the above (Limited potential impact on environment).	Low (1)
None of the above (No potential to degrade the environment or otherwise affect ecosystems).	Negl. (0)

S. inaequidens

Rationale for Rating:
Although *S. inaequidens* primarily invades disturbed sites, it has become established in natural areas, such as alpine fields, heathlands, and rocky sites on the edges of rivers (Heger and Trepl, 2000; Bornkamm, 2002; Roca, 2003; Rzedowski *et al.*, 2003). Because it forms dense populations of 5 to 15 plants per square meter (Sans *et al.*, 2004), it can exert competitive pressure on native species (primarily through shading). One study reported that it is not a very good competitor (Scherber *et al.*, 2003), which would explain why it colonizes open and disturbed habitats; however, another study indicated it does not suffer much from intraspecific competition (Bornkamm, 2002). Evidence exists that it outcompetes some herbs, such as willowherbs (*Epilobium angustifolium* and *E. hirsutum*) and creeping thistles (*Cirsium arvense*) (Heger and Trepl, 2000). Thus, *S. inaequidens* may have a negative impact on biodiversity (Bornkamm, 2002), although this has not yet been tested (EPPO, 2004). It may also be having an impact on community

Senecio inaequidens is unusual in that it is a perennial that can establish and produce offspring in the same year, behaving as an annual. But, as a perennial it accelerates community succession from a pioneer to early successional communities (Bornkamm, 2002), thereby affecting ecosystem processes.

Like *Senecio madagascariensis*, *S. inaequidens* produces pyrrolizidine alkaloids, which are toxic to herbivores, cattle and humans (CABI, 2004). Grain and flour products contaminated with *Senecio* seeds can cause human fatalities (Altaee and Mahmood, 1998). Heger (2000) states that in Africa, *S. inaequidens* is a weed in croplands and pastures, and that its poison is repeatedly found in milk and bread; he mentions cases of lethal poisoning.

Because *S. inaequidens* is invasive and poses economic and health risks (see above), its introduction to the U.S. would likely stimulate control programs that would include the use of herbicides. Several exotic *Senecio* species, already present in the United States, are under control by various government agencies (*e.g.*, *S. jacobaea*, DNRP, 2005).

Overall, although *S. inaequidens* does not pose a clear and strong threat to natural resources, the uncertainty of its potential effect and the negative impact it can have on human health merits a risk rating of High.

Certainty of Rating: Medium
Risk Rating: High

S. madagascariensis

Rationale for Rating:
Plants of *S. madagascariensis* can reach densities of 12 plants per square meter and maintain soil seed banks of 12,000 seeds per square meter (Sindel *et al.*, 1998). High densities of this invader are negatively associated with densities of some favorable pasture species, while positively associated with others (Radford *et al.*, 1995). Results from several surveys of *S. madagascariensis* in Australia indicate it is a long-term invader, and not a transient invasive

species (Radford *et al.*, 1995). .

S. madagascariensis is associated with other exotic species in natural habitats (Staples *et al.*, 2002) and has spread to natural parks and reserves in Hawaii (Starr *et al.*, 2003). In Australia, pollinators visited flowers of *S. madagascariensis* and a native congener when both species were growing intermixed (Sindel *et al.*, 1998). If reproduction of native species is pollinator-limited, then the invasion of *S. madagascariensis* would reduce the reproductive efforts of native *Senecio*s due to competition for pollinators.

The U.S. contains dozens of native species of *Senecio* which live in a variety of habitats, including disturbed habitats (*e.g.*, Hickman, 1993; Welsh *et al.*, 1993). Two species, *S. franciscanus* and *S. layneae,* are federally listed as threatened (USFWS, 2005b). *Senecio layneae*, occurs in the Mediterranean habitats of Coastal California (USFWS, 2005a), similar to the habitats where *S. madagascariensis* is native in South Africa. If *S. madagascariensis* establishes in the U.S., it would likely invade this habitat, threatening the existence of *S. layneae* through competition or indirectly through hybridization. Many species in *Senecio* freely interbreed if they come into contact with each other (Abbott, 1992; Welsh *et al.*, 1993).

Senecio madagascariensis produces pyrrolizidine alkaloids, which are toxic to humans and animals if ingested (Sindel *et al.*, 1998). Cases of human poisoning have been reported in Argentina (Bohmer, 2001 in Rzedowski *et al.*, 2003) and elsewhere with other species of *Senecio* (Altaee and Mahmood, 1998).

Because of the threat that *S. madagascariensis* poses, the establishment and invasion of *S. madagascariensis* would stimulate control efforts, as already seen in Australia and Hawaii (Sindel *et al.*, 1998; Starr *et al.*, 2003; Arakaki, 2005b).

Certainty of Rating: High
Risk Rating: High

Economic and Environmental Importance Summary

The economic and environmental consequences of invasion by *S. inaequidens* and *S. madagascariensis* was summarized by adding the risk ratings for the above four elements. A new risk score was generated for the Consequences of Introduction of these species according to the table below; this score is an indicator of 1) the potential of the species to become established and spread, and 2) the potential to cause economic and environmental impacts. The cumulative risk element score for *S. inaequidens* is 11 (3 + 3 + 2 + 3, respectively), which represents a risk rating of High. The cumulative risk element score for *S. madagascariensis* is 11 (2 + 3 + 3 + 3, respectively), which represents a risk rating of High.

Table 1. Final risk rating for Consequences of Introduction based on the cumulative score from the four previous risk elements.

Cumulative Risk Element Score	Rating	*S. inaequidens* Score	*S. madagascariensis* Score
0-2	Negl. (0)	High (11)	High (11)
3-6	Low (1)		
7-10	Med. (2)		
11-12	High (3)		

Step 6. Assess Likelihood of Introduction / Spread

The likelihood that an exotic weed will be introduced depends on the number of associated pathways and, within each of these pathways, the weed's opportunity to survive and find a suitable habitat. The final step of a weed risk analysis is an estimation of this likelihood. This qualitative risk rating includes, but is not limited to, consideration of the factors listed below. Those that applied to *S. inaequidens* and *S. madagascariensis* were indicated with an **I** or **M**, respectively.

- Interest in cultivation of the species for ornament, food, medicine, or other uses.
- Evidence of previous importation (**M**).
- Species prevalence in the area of origin (**I,M**).
- Potential for contamination of commodities or conveyances by the species (**I,M**).
- Whether the species can survive under the environmental conditions of shipment (**I,M**).
- Difficulty in detection through visual inspection.
- Probability of surviving existing phytosanitary procedures.
- Frequency and quantity of pest movement into the PRA area by named means.
- Number and frequency of shipments of contaminated commodities (**I,M**).
- Number of individuals of the species associated with each named conveyance or commodity (**I,M**).
- Intended use of named commodities (**I,M**).
- Season of arrival and distribution of commodities.

Explanation	**Rating**	**Score**
Very likely or certain, given the combination of factors above.	High (3)	High (3)
Likely	Med. (2)	
Low, but clearly possible.	Low (1)	
Extremely unlikely.	Negl. (0)	
Rationale for Rating: Because *S. inaequidens* and *S. madagascariensis* are congeners that occur in similar habitats and have similar life histories and seed morphology, there was no reason to believe they would differ in their Likelihood of Introduction. Consequently, they were jointly considered		

and analyzed.

Abundance in Infested Areas: *Senecio inaequidens* and *S. madagascariensis* occur in a variety of habitats, being particularly abundant in disturbed and pasture areas, respectively (Ernst, 1998; Sindel *et al.*, 1998). They can be found at densities of 5 to 15 plants per square meter, or more, (Sindel *et al.*, 1998; Sans *et al.*, 2004) depending on the life history stage being examined. Because they can produce over 100 seeds per capitulum and over 100 capitula over an extended flowering season, each plant could easily produce over 10,000 seeds (Sindel *et al.*, 1998; Lopez-Garcia and Maillet, 2005). Seed densities of 12,000 per square meter have been counted for *S. madagascariensis* (Sindel *et al.*, 1998). Thus, given their abundance and highly prolific reproduction, both species have ample opportunity to contaminate or become associated with a specific pathway into the United States.

Pathways for Introduction: One of the most common pathways for weed introduction and establishment is as propagative materials, where they are deliberately introduced and cultivated. Although there are dozens of *Senecio* species that are cultivated around the world, neither *S. inaequidens* nor *S. madagascariensis* is under cultivation (Page and Olds, 2001); however, several other pathways remain that may allow for their introduction.

Asteraceae are typically herbs, vines, and small shrubs that produce numerous seeds. Most seeds have a pappus (small, feathery parachute structure) that facilitates wind dispersal (Cronquist, 1981). With a copious number of seeds in produced, Asteraceae seeds could easily contaminate many different products and enter the U.S. through a variety of different pathways. Since 1984, there have been 388 interceptions of Asteraceae species at U.S. ports. Most were intercepted as contaminants in seed products and other plant parts, such as fruit, cuttings, stems, leaves, *etc*. (Fig. 3). Asteraceae seeds have also been intercepted on baggage, dried plant material, wheat, granite, military household goods, clothing, crating, machinery, packing material, straw, tiles, and wool (PIN-309, 2005). Below are some specific pathways that *S. inaequidens* and *S. madagascariensis* have followed.

1. Wool Imports: *Senecio inaequidens* was introduced to Europe at several different sites with wool imports (Ernst, 1998). Within South Africa, it has been redistributed to locations outside of its natural range via wool trade/production (Lafuma *et al.*, 2002). Given the structure of wool, it should not be surprising that sheep that are feeding in areas infested with *Senecio* species should act as seed vectors.
2. Contaminant in Seed Products: As discussed above, *Senecio* species have been implicated in human poisoning from wheat and other food products contaminated with *Senecio* seeds. Bags of *Triticum* seed (wheat) have been intercepted at U.S. ports with Asteraceae seeds (PIN-309, 2005). In Hawaii, *S. madagascariensis* germinated in hydromulch that used carpet grass seeds (*Axonopus fissifolius*) from Australia (Arakaki, 2005b). Within Australia, *S. madagascariensis* has been spread in crop seed (Green, 1953; Sindel *et al.*, 1998).
3. Ballast Water: Given its distribution in coastal habitats, seeds of *Senecio madagascariensis* may enter a country in ship ballast water, as it may have in Australia (Sindel *et al.*, 1998). At least one other species of Asteraceae, with seeds adapted for wind dispersal are dispersed along waterways, remaining viable for seven

days or more (Craddock and Huenneke, 1997).

4. Straw and Feed: Hay bales obtained from pastures containing *Senecio* will undoubtedly be contaminated with hundreds of wind-dispersed seeds. For example, in Australia, contaminated cattle feed has contributed to the dispersal of *S. madagascariensis* in Australia (Sindel *et al.*, 1998).
5. Miscellaneous Surfaces: Small populations of *Senecio* produce large amounts of seeds which could readily contaminate and enter the U.S. on the surfaces of many objects (see PIN-309 interceptions above) (EPPO, 2004). For example, contamination of train cars in Europe contributed to the spread of *S. inaequidens* along railways (Ernst, 1998). In Hawaii, *S. madagascariensis* was introduced on fencing material to Haleakala National Park (Starr, 2005).
6. Potting Soil Contamination: Although the U.S. regulates the importation of soil into the country, within the country, seeds of *Senecio* species may be redistributed in the soil of potted plants. For example, the Oahu Invasive Species Committee reported potted Koa seedlings infested with *Senecio* seeds was transported from the island of Hawaii to Oahu and planted in conservation areas (Arakaki, 2005a).

Probability of Surviving Shipment: Seeds of *Senecio inaequidens* and *S. madagascariensis* have a dormancy period and can remain viable for long periods of time (several months to years) (Ernst, 1998; Sindel *et al.*, 1998). It is likely that seeds would survive transportation under most conditions. While seeds of *S. inaequidens* can tolerate freezing temperatures down to -15˚C (Ernst, 1998), it is unknown how sensitive seeds of *S. madagascariensis* are to cold. It is unknown how standard phytosanitary treatments (*e.g*., dips, fumigation, cold storage, *etc*.) would affect the viability of *Senecio* seeds.

Probability of Not Being Detected at the Port-of-Entry: Inspectors at U.S. ports inspect samples of all commodities, including the crates and vehicles used for transport. *Senecio* seeds are large enough to be noticed if present (1.5-2.5 mm long (Hilliard, 1977), especially if they retain their pappus; however, because it is impossible for inspectors to examine everything and all surfaces, some *Senecio* seeds will probably pass inspection. Even if these two *Senecio* species were listed as Federal Noxious Weeds, some risk remains that they will pass inspection due to the difficulty in distinguishing them from other aster and *Senecio* species based on seed characteristics alone.

Likelihood of Encountering a Suitable Habitat: Based on USDA Plant Hardiness Zones, both *Senecio* species are able to establish in the southern third of the United States. California's Mediterranean-like environments may be particularly suitable *Senecio* establishment. Given the volume of transport and trade with Mexico, where *Senecio inaequidens* is already established in one area (Rzedowski *et al.*, 2003) and given that agricultural grass seeds contaminated with *S. madagascariensis* have already passed through Los Angeles (Arakaki, 2005b), the likelihood that either *Senecio* species will be transported to a suitable habitat is very high. As *S. inaequidens* continues to spread in Mexico, the likelihood that it will follow a pathway to the U.S. will increase.

Opportunity for Establishment. Once *Senecio* seeds have been transported to a suitable habitat, they must come into contact with a suitable substrate to germinate. Evaluating this likelihood is always difficult, due to the lack of data that describe and quantify this process; however, in the case of *S. inaequidens* and *S. madagascariensis*, this likelihood was estimated to be High because both species are associated with disturbed habitats. Seeds picked up in foreign locations will most likely be transported to other disturbed/anthropogenic habitats where they can become dislodged and land on a suitable substrate. If *Senecio* seeds enter as contaminants of seeds for planting (*e.g.,* those used in hydromulch), they will eventually establish in the continental U.S., as they have on three separate occasions in Hawaii (Starr, 2005).

Conclusion: It is estimated that the overall Likelihood of Introduction for *S. inaequidens* and *S. madagascariensis* is High. Confidence in this rating is bolstered by the fact that nine other species of *Senecio* have entered and established viable populations in the U.S. (USDA-NRCS, 2005).

Certainty of Rating: Very High.

Risk Rating: High

Step 7. Conclusion / Pest Risk Potential (PRP): Determine if Weed Should be Listed.

The pest risk potential of a species is a qualitative estimate that is obtained by considering the results from the Consequences of Introduction and the Likelihood of Introduction listed above. These estimates are then combined in accordance with the U.S. Guidelines for Weed Risk Assessment (v. 5.3; USDA, 2004). Both *Senecio inaequidens* and *S. madagascariensis* were assessed to have a High Likelihood of Introduction and a High Consequence of Introduction, resulting in an overall Pest Risk Potential of High. A High Pest Risk Potential qualifies these species for consideration as federal noxious weeds (USDA, 2004). Neither species is currently regulated by federal law. The results of this assessment indicate *S. inaequidens* meets the definition of a “quarantine pest” because it is not known to occur in the U.S. and it has potential economic consequences. *Senecio madagascariensis*, which is present on several Hawaiian islands, has a relatively limited distribution (Starr and Starr, 2005) and is under official control.

Senecio inaequidens and *S. madagascariensis* are herbs that are invasive in a variety of habitats. Their high reproductive capacity, coupled with their potential for long-distance dispersal have made them noxious weeds where they occur. *Senecio* species produce pyrrolizidine alkaloids that are toxic if consumed. Consumption of wheat contaminated by *Senecio* seeds can lead to human fatalities. *Senecio inaequidens* and *S. madagascariensis* are considered noxious weeds not only where they have been introduced, but also in their native range in Africa. Because these species are difficult to control once established, it would be much more effective to prevent their entry into the United States. This weed risk assessment determined that these two species pose a High Pest Risk Potential for the United States, and recommends that they be considered for listing as federal noxious weeds.

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Step 8. Document the PRA: Literature Cited

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Figures

Figure 1. *Senecio madagascariensis*: an herb. Image taken by Forest and Kim Starr (USGS; starr-040723-0532). Copyright permission obtained (Starr, 2005).

Figure 2. ***Senecio madagascariensis*** **in a Hawaiian pasture. Photo taken by Forest and Kim Starr (USGS; starr-040723-0532). Copyright permission obtained (Starr, 2005).**

Figure 3. Types of products and surfaces on which seeds of Asteraceae species have been intercepted at U.S. ports-of-entry (1984 to 2005) (N=388; PIN-309 query June 7, 2005) (PIN-309, 2005).