KISC KAUAI INVASIVE SPECIES COMMITTEE	Kauai Status	KISC Status	HPWRA	Invasive Impacts Score	Feasibility Score	Combined Score
Pueraria montana (kudzu)	**NATURALIZED**	**RAPID RESPONSE**	**HIGH RISK (24)**	**8**	**7**	**15**

Initial PFC report completed: October 2017
PFC report updated as of: N/A
Current Recommendation for KISC: Accept as KISC Target pending scoring rank and committee review
Knowledge Gaps and Contingencies:

1) Delimiting surveys surrounding known locations are required to gain knowledge of the extent of clonal populations.
2) Early detection surveys should be conducted in herbarium voucher locations.
3) Outreach efforts are crucial to increase detection by citizens on private land.
4) An assessment of potential control methods, particularly near the Hanalei river, is required.
5) An understanding of partnership roles may increase the likelihood/rate of success.
6) Spread by roadside mowing must be communicated to country roadside maintenance crews.

Background

Pueraria montana (Fabaceae) or "kudzu", is a large, clonal, herbaceous vine that has gained infamy in southeastern USA as a noxious weed directly responsible for substantial ecological and economic losses (Sun et al. 2005). Interestingly, *P. phaseoloides* is listed as a noxious weed by the Hawaii Department of Agriculture while *P. montana* is not, even though invasive impacts from *P. montana* are more frequently reported in the literature. The most common variety found in Hawaii and throughout USA is *P. montana* var. *lobata,* however, *P. montana* var. *chinensis* has also been recorded on Kauai (Imada 2012). These two varieties are hard to differentiate morphologically, and the taxonomy has been confused in the literature such that a number of different names are used to refer to plants invading USA (Sun et al. 2005). To remove taxonomic confusion, this report will not distinguish between varieties.

P. montana gained a KISC status of "Rapid Response" in June 2017, when delimiting surveys and simultaneous control of this plant by KISC began. Although most species undergo a prioritization assessment prior to implementing control efforts, this step was bypassed due to the small number and apparently manageable size of existing populations and infamous invasive reputation of this plant. Additionally, KISC was able to take advantage of help from Hanalei National Wildlife Sanctuary staff, who have *P. montana* within their lands. This follows the rapid response decision-making pathway outlined in KISC's 2017-2022 strategic plan (KISC 2017) and presented in Table 5 in KISC Plant Early Detection Report. Thus, the purpose of this prioritization assessment report is to inform whether KISC should continue to commit resources towards island-wide eradication of *P. montana,* thereby shifting this species to "Target" status. Ongoing control efforts may reveal additional information that will be discussed during committee meetings and incorporated into this report at a later date.

Detection and Distribution

P. montana was first vouchered on Kauai in 1971 (Herbst 2219, BISH), although it was likely introduced much earlier by Chinese immigrants in the late 1800's who harvest the edible tuber (Degener 1934). The earliest collection within the state is from Hawaii Island in 1915 (C.N. Forbes, 522.H) and it is also present on Oahu and Maui. Despite its reputation as an invasive weed and long history in Hawaii, *P. montana* is only known from four confirmed locations on Kauai (Figure C36- 1). However, these instances are widely distributed, occurring in Hanalei, Kawaihau, Waimea and Koloa districts, of which only two were detected during 2015-2017 surveys. A third occurrence of *P. montana* was present in Halemanu, Kokee, but was eradicated by Kokee Resource Conservation Program (KRCP) in 2010. The forth location derives from a herbarium collection from 1971, which states that it was collected from a "vacant lot near Kumu-o-kalani" (Herbst 2219, BISH). Roadside surveys conducted in this area failed to detect *P. montana*, and thus, additional surveys within private lots should be conducted to ensure the plant hasn't persisted.

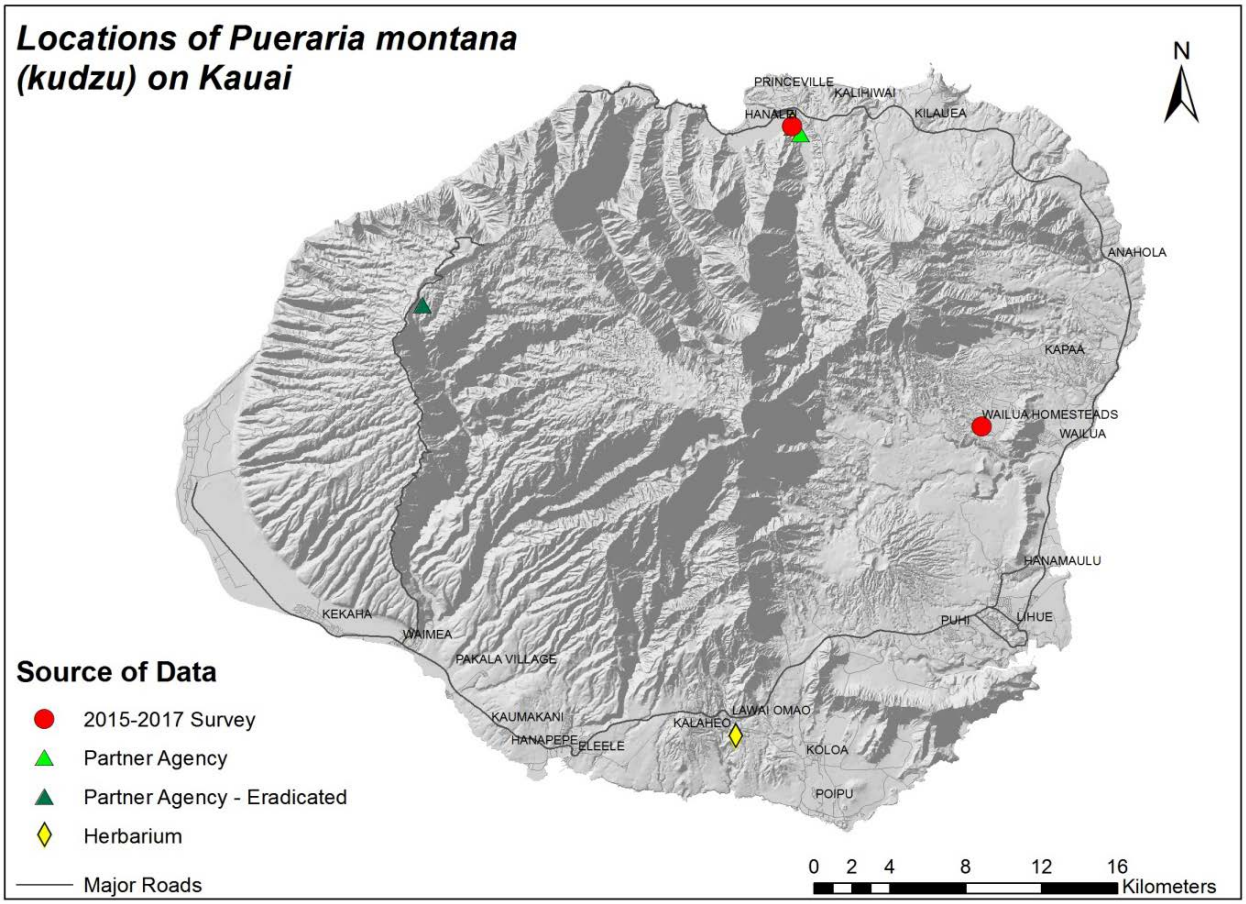

Figure C36- 1. Locations of *P. montana* on Kauai. Locations where presence of the plant was confirmed during 2015-2017 surveys are denoted by red circles.

Hawaii Pacific Weed Risk Assessment (HPWRA) Score

P. montana is designated as "High Risk", receiving a score of 24 (Daehler et al. 2004, HPWRA 2008). Traits contributing to this status are listed below according to whether they pertain to the likelihood a plant will invade vs. the consequences of the invasion, according to Daehler and Virtue (2010). Categorization of traits in this manner more accurately informs invasive impact potential scoring and prioritization of species that are already established on Kauai.

Likelihood of Invasion	*Consequences of Invasion*
• Well suited to climates in Hawaii • Repeatedly introduced and naturalized in areas with comparable climates • Shade tolerant • Tolerate a wide range of soil conditions • Underground storage organ • Produces viable seed • Reproduction by vegetative fragmentation • Propagules dispersed intentionally and unintentionally by people • Propagules bird dispersed, surviving passage through the gut • Not well controlled by herbicides • Benefits from fire	• A weed of native ecosystems, agriculture and gardens/disturbed areas • A congeneric weed, sharing a genus with the known invasive *P. phaseoloides* (i.e. implies inheritance of tendencies to inflict invasive impacts) • Alternate host for soybean rust • Climbing and smothering growth habit forms dense thickets • Nitrogen fixer

Refer to the full Weed Risk Assessment for *P. montana*, including how these traits and characteristics traits affect HPWRA scoring, at https://sites.google.com/site/weedriskassessment/assessments/Download-Assessments.

Invasive Impacts Score

It is important to note that *P. montana* has been present in the Hawaiian islands likely since the late 1800's (Degener 1934), which is supposedly long enough to establish and spread (Sun et al. 2005). Despite this, few invasive impacts to Hawaii have been noted and populations remain much smaller and less damaging than those described in southeast USA (but see Starr et al. 1999). Two speculations may explain this phenomenon. Firstly, 134,760 hectares (333,000 acres) and millions of *P. montana* seedlings were planted in close proximity to prevent soil erosion in southeastern USA in the 1930-40's (Sun et al. 2005), whereas *P. montana* has been cultivated more sparsely as a food plant in Hawaii. Thus, perceived differences in invasive impacts in Hawaii vs southeastern USA may be due to vastly different amounts of introduced founder plants, and that a longer lag time is necessary in Hawaii to see comparable impacts. Secondly, genetic studies revealed that *P. montana* is exceptionally diverse throughout its large native range of China, Korea and Japan, and a single or very few introductions are responsible for invasions in southeast USA (Bentley and Mauricio 2016). It is thought that southeast USA introductions may largely be from Japan (Sun et al. 2005, Bentley and Mauricio 2016), while *P. montana* in Hawaii is thought to be from China (Degener 1934). Hence, genetic variability arising from introduction events from different regions may account for apparently diminished invasive behavior in Hawaii when compared to southeastern USA.

Although these knowledge gaps make scoring the potential impacts of *P. montana* difficult, scoring in this report has conservatively assumed that impacts comparable to those in southeast USA are possible despite its long history as a minor weed when compared to other ecosystem-altering weeds in Hawaii. Invasive Impact scoring and rationale for *P. montana* is presented below. Refer to Appendix A for details regarding the Invasive Impact Score.

1. Impact on natural community structure and/or composition

Score: 2 = Moderate impacts

P. montana was assigned a score of 2 because of its ability to kill shrubs and trees by smothering (light starvation and crushing) and girdling (constriction causing injury to the stem). *P. montana* is known to rapidly colonize light gaps in native forests, preventing re-establishment of native tree species (Forseth and Innis 2004). Importantly, a small clonal population in Kokee, Kauai was noted at an elevation of 1070m covering several large koa (*Acacia koa*) trees, an important dominant native forest species (Cassel 2017). While this population has been eradicated, it exemplifies that *P. montana* is capable of growing in valuable high-elevation native habitats. However, *P. montana* was scored a 2 rather than a 3 because of its strongly clonal nature. Outcrossing is required to produce seed consistently, although seed set has been rarely recorded (Pappert et al. 2000). Population genetics studies estimate 80% of the infestation in southeastern USA was produced vegetatively (Pappert et al. 2000, Sun et al. 2005, Bentley and Mauricio 2016). Similarly, a review of herbarium vouchers revealed that seed has never been documented in Hawaii. As current populations are located a long distance away from native-dominated habitats, spread into these areas will likely not occur in the near future. However, it should be noted that the largest population of *P. montana* lies within a POPREF polygon (Hanalei - HAN) also containing PEP plants.

Figure C36- 2. *P. montana* south of Hanalei National Wildlife Refuge. Herbarium vouchers from the same area indicate that this population has been present for at least 26 years (T. Flynn 4748, PTBG).

2. Impacts to Agriculture, Culture and other Human Systems

Score: 3 = Major impacts

P. montana received a score of 3 due to abundant reports of this plant rapidly colonizing disturbed areas and causing significant economic damage by smothering agricultural fields, forestry plots, yards and urban areas (Starr et al. 1999, Forseth and Innis 2004). Additionally, the largest known population is adjacent to the Hanalei Wildlife Refuge, which contains 180 acres of taro patches. Taro is a culturally important crop that was once a staple of native Hawaiians. *P. montana* is also an alternate host for soybean rust, a disease causing up to 80% yield loss in soybeans in some cases (Slaminko et al. 2008).

3. Impacts to biotic and abiotic processes

Score: 3 = Major Impacts

P. montana was assigned a score of 3 due to: 1) the ability of this plant to influence soil nutrient cycling via nitrogen fixation (Forseth and Innis 2004, Lindgren et al. 2013), 2) the potential for high above and below ground biomass to uptake large quantities of water, thereby affecting soil moisture (Forseth and Innis 2004) and, 3) the propensity of this plant to transmit fungal pathogens (known to spread to other members in the same family (Slaminko et al. 2008)) and *Phytophthora* water mold (known to broadly infect plants in both native and agricultural systems (Rahman et al. 2014)). The largest population of *P. montana* is adjacent to the Hanalei National Wildlife Refuge, and while this area is predominantly agricultural, it provides important habitat for native water birds.

TOTAL INVASIVE IMPACTS SCORE: 8

Feasibility of Control Score

Feasibility of Control Scoring and rationale for *P. montana* is presented below. Refer to Appendix A for details regarding the Invasive Impact Score.

Delimiting Survey:

Score: 2 = Moderate Effort

Feasibility of a delimiting survey for *P. montana* was given a score of 2 because there are only 4 known sites of interest, one of which has been eradicated and one that hasn't been detected since 1971. Existing sites are reasonably small and due to its clonal nature, conducting delimiting surveys around the edge of each patch should be easy to visualize. Hanalei National Wildlife Refuge staff began collaborating with KISC in July 2017 and located 2 additional small patches within 700m of the patch detected from the roadside (Figure C36- 3) . However, the long history of *P. montana* in Hawaii as a food plant indicates that more sites are likely present on Kauai, especially on private property. Significant outreach efforts are necessary to increase the likelihood that citizens will report locations on private property that cannot be detected from roadsides. However, many tri-lobed vines in the same family (Fabaceae) are present on Kauai, and false reports requiring KISC staff to investigate the site area likely. Given the number of patches located along the Hanalei river, a boat survey (or similar) should be conducted to determine is vegetative fragments have established downstream.

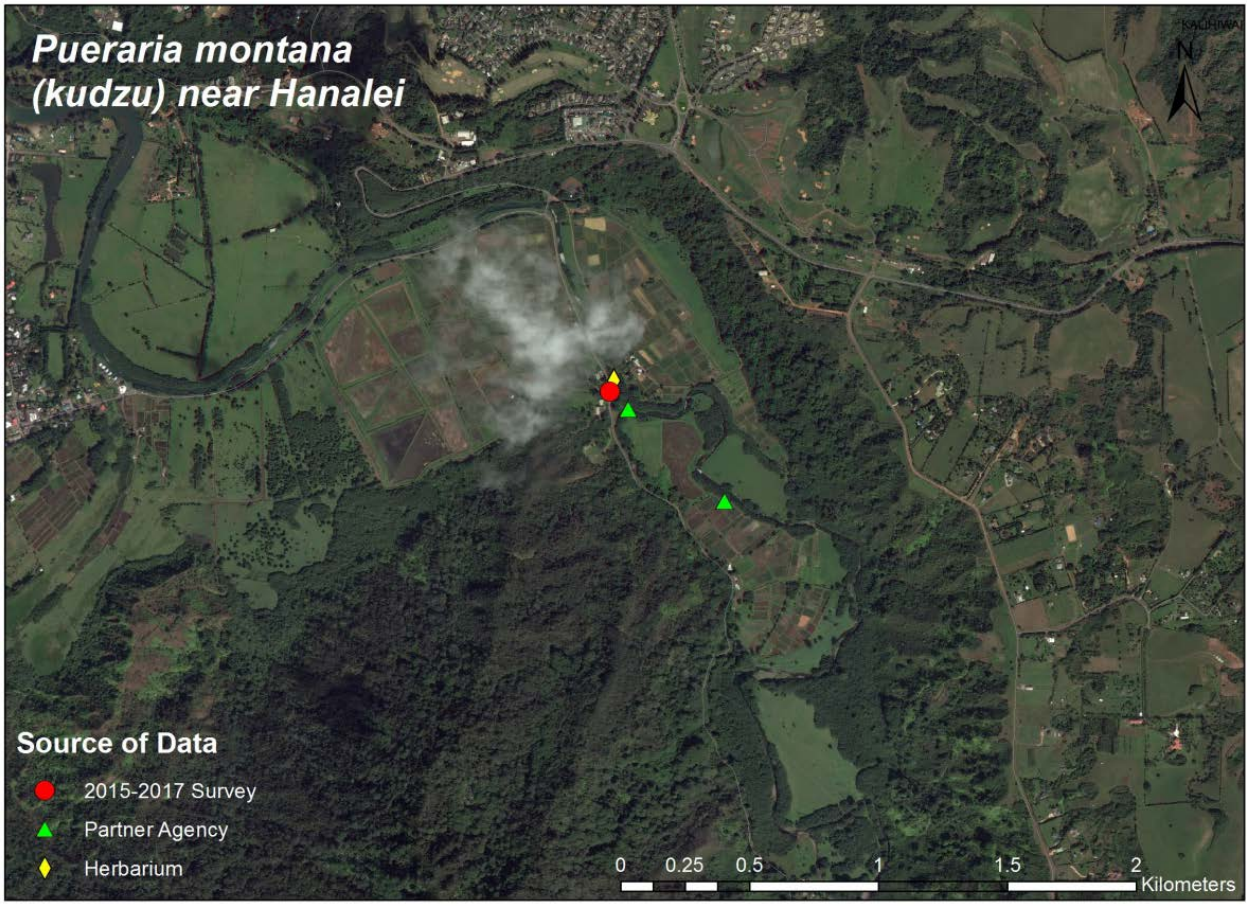

Figure C36- 3. Map of *P. montana* locations near Hanalei, with red circles denoting locations found during 2015-2017 surveys, green triangles indicating locations reported by the Hanalei National Wildlife Refuge biologist, and yellow diamonds indicating the approximate location of a herbarium voucher from 1991.

Initial control:

Score: 2 = Moderate Effort

Feasibility of initial control for *P. montana* was given a score of 2 because known patches are fairly small - the largest patch comprising <20% cover of an approximately 100 meter X 3 meter area, between the Hanalei river and roadside. However, control to the point of eradication of this plant is notoriously difficult due to large underground storage organs that persists after herbicide treatment despite significant research effort (Minogue et al. 2011). Studies note that death of the entire plant usually takes 8-10 years, which indicates that death occurs from starvation by constant defoliation, rather than eventual herbicide translocation to the tuber. Furthermore, pesticide use next to the Hanalei National Widllife Refuge will be problematic. The Kokee patch was eradicated by KRCP after 8 years experimenting with many herbicide and application methods including Garlon 4, Escort XP and Round Up, with sluggish success. Eventually, manual removal of the main tuber approximately 1 meter long by 30cm wide eradicated the small clonal patch (Cassel 2017). After exploring control options, KISC may wish to downgrade this score to a 1 for "Major Effort" if manual removal of multiple tubers is the only option. Additionally, studies have shown that roadside mowing and maintenance, which disperses vegetative fragments, is a significant factor contributing to population expansion in southeastern USA (Cheng et al. 2007). This appears consistent with plants in Kauai, where the largest patch lies immediately next to Ohiki Road, and is distributed narrowly along the ditch. Coordination with the County of Kauai, who maintains vegetation along the roadside, is necessary to prevent further spread of *P. montana* in this area.

Monitoring:

Score: 3 = Minimal Effort

Feasibility of monitoring for *P. montana* was given a score of 3 because its mainly spreads by vegetative propagation, and seed set is rare. Furthermore, outcrossing is usually required to produce seed (Pappert et al. 2000). Thus, no seedbank should persist after initial control of all plants (including underground structures). However, minimal monitoring in subsequent years is required to ensure emergent stems from undetected tubers are not present.

FEASIBILTY OF CONTROL SCORE: 7

COMBINED SCORE= 8 + 7 = 15

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