KISC KAUAI INVASIVE SPECIES COMMITTEE	*Kauai Status*	*KISC Status*	*HPWRA*	*Invasive Impacts Score*	*Feasibility Score*	*Combined Score*
***Salix* sp.** (willow)	**NATURALIZED**	**EARLY DETECTION**	**?***	**(6 or 8)****	**8**	**14** or **16****

Initial prioritization report completed: January 2017
Report updated as of: N/A
Current Recommendation for KISC: pending scoring rank and committee review
Knowledge Gaps and Contingencies:

1) Delimiting surveys surrounding known locations are required to determine the extent of the infestation
2) An understanding of partnership roles may increase the likelihood of success.
3) Additional efforts to resolve the identity of this species are highly recommended

* An HPWRA score is not available due to the uncertain identity of this species
** A score of 6 or 8 is suggested, depending on the final identification of the plant

Background

The genus *Salix* (Salicaceae) is a genus of woody shrubs or trees commonly referred to as "willows". They are sometimes cultivated as ornamentals or are used in soil restoration and agroforestry projects (Adair et al. 2006). The use of *Salix* sp. in this report refers to a specific plant of unknown identity detected in Kokee during 2015-2017 surveys (Figure C38- 1). Only immature reproductive material was present at the time of collection and more information regarding seed viability, wood/bark patterns and catkin morphology is required to determine the identity of these plants. However, species within the genus *Salix* are notoriously difficult to identify, owing largely to their variable morphological characteristics and extensive hybridization (both natural and human-induced) with other members of the genus (Meikle 1992, Argus 2003, Fogelqvist et al. 2015). The *Salix* sp. detected in Kokee has so far been identified to the genus *Salix*, Subgenus *Vetrix*, Section Vetrix (Argus 2003, Chen et al. 2010), which contains known invasive members. Although field notes and vouchers collected from 2015-2017 surveys were not sufficient to confirm the identification, future field collections should be compared to *S. atrocinerea*, *S. caprea*, *S. cinerea, S.* x *calodendron* (a hybrid of *S. caprea*, *S. cinerea* and *S. viminalis*) and *S.* x *reichardtii* (a hybrid of *S. caprea* and *S. cinerea*). These species and hybrids have been introduced outside of their native range and are the most morphologically similar to specimens collected from Kokee (Matthew et al. 2008). Thus, these taxa are likely candidates for final identification, although other species within Section Vetrix should not be ruled out.

Unfortunately, the taxonomy of these species is important to predict potential invasive impacts in this group as hybrids are sterile. However, hybrids are apparently able to naturalize over surprisingly large areas through vegetative reproduction (Cremer 2003, Matthew et al. 2008, PlantNET. 2017). Both *S.* x *calodendron* and *S.* x *reichardtii* are known to be sterile, and both are naturalized in Australia and New Zealand. The current morphological data combined with distribution patterns observed in the field suggest that plants found in Kokee may more likely be *S. caprea* or *S. cinerea*. However, due to the high degree of taxonomic uncertainty and great differences in invasive potential for closely related species and hybrids, an identity has not been assumed throughout this report. Given the limited known distribution of this plant on Kauai and its location near high-value native habitat, KISC and/or its partners may choose to eradicate *Salix* sp. from Kokee despite taxonomic uncertainty. However, it would be very beneficial to collect additional reproductive material from the naturalized population before eradication, as the confirmed identity will be crucial for management decisions if this plant is encountered again on Kauai or neighboring islands. Collection trips in January-April may be most successful as past trips in November, May and July have not yielded any flowers or fruits, although immature catkins could be dissected out of the buds collected in November. Many *Salix* species flower for only a 3 week period (Matthew et al. 2008). *Salix* sp. has not been considered for control by KISC in the past and thus, the purpose of this prioritization assessment report is to evaluate whether KISC should attempt eradication (i.e. accept "Target" status) or joint control with partnering agencies (i.e. accept as "Partnership" species status). This will be informed by scoring and comparing *Salix* sp. to other "Early Detection" species known to Kauai (See Table 5 in KISC Plant Early Detection Report for status terminology).

Detection and Distribution

Salix sp. was first detected on Kauai during 2015-2017 surveys from a naturalized population in Waineke swamp in Kokee (K. Brock 921, PTBG). No species in the genus *Salix* have been recorded as naturalized on any Hawaiian island (Imada 2012). Approximately 40 mid-sized, multi-branched trees of different age classes were observed naturalizing from Camp 10 road, although the understory was not searched for smaller individuals. The trees do not form a continuous thicket, but comprise a considerable percentage of the canopy in a portion of the swamp due to their large size and densely branching habit (Figure C38- 2). This distribution pattern is usually indicative of seed-producing *Salix*, as vegetative species often form thick stands by root suckering or layering (where roots are produced where branches touch the ground). However, a few horizontal stems, which are sometimes indicative of vegetative reproduction (or possibly just unstable soil), were also noted during field surveys (Matthew et al. 2008). So far, these data indicate that *Salix* sp. is currently naturalized within one district (Waimea) and one watershed (Waimea).

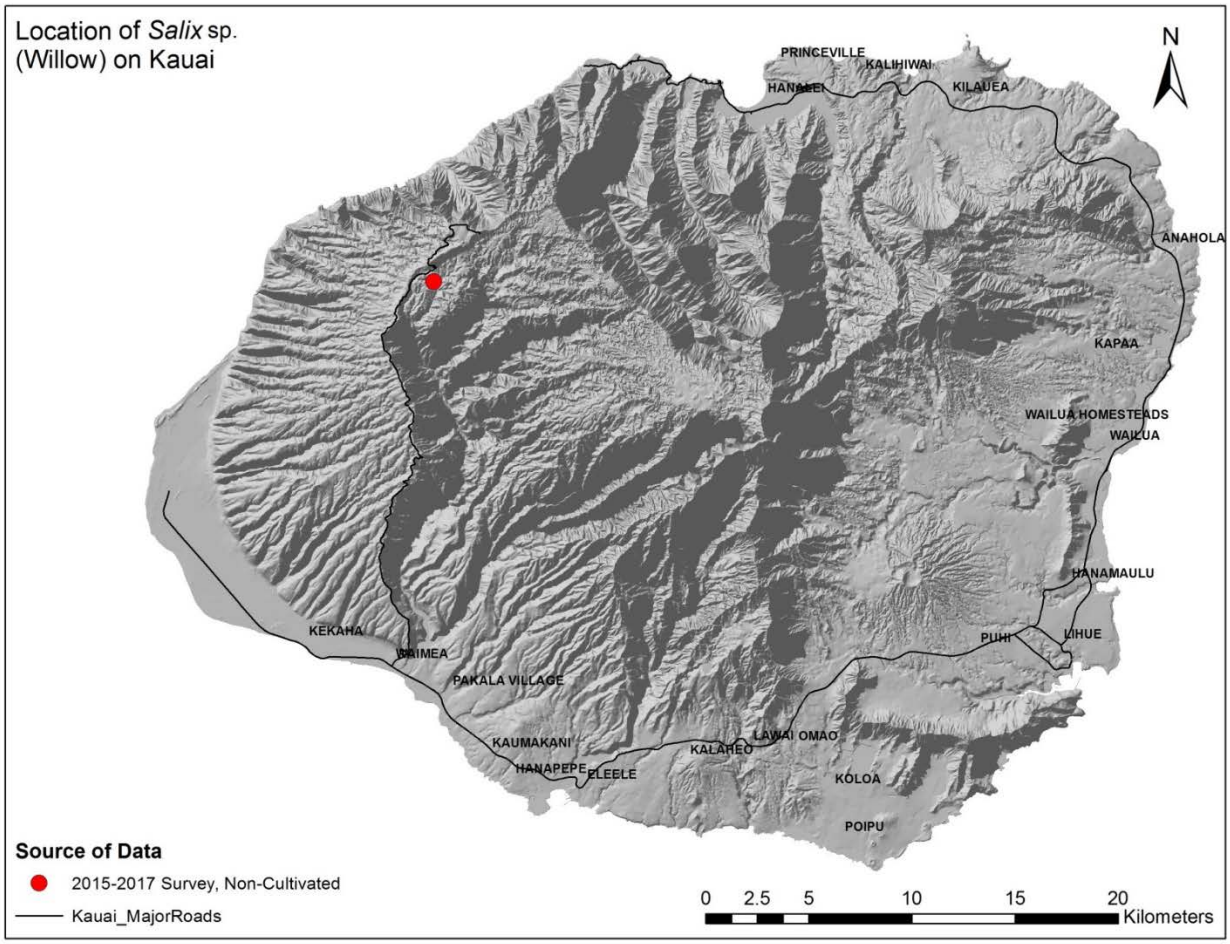

Figure C38- 1. Location of *Salix* sp. on Kauai.

Figure C38- 2. Photo of *Salix* sp. (with large trees denoted by red arrows) naturalizing in Waineke swamp.

Hawaii Pacific Weed Risk Assessment (HPWRA) Score

Due to the uncertain identity of *Salix* sp. discussed in this report, a specific weed risk assessment is not referred to in this section. However, two species within Section Vetrix in the genus *Salix* (see Background Section above) have been evaluated and are available within the HPWRA database, including *S. cinerea* (HPWRA 2018) and *S.* x. *reichardtii* (HPWRA 2017). These species were ranked as "High Risk" receiving a score of 9, and "Low Risk" receiving a score of 2, respectively, illustrating the considerable difference in invasive traits between a species and a hybrid.

Invasive Impacts Score

A higher than normal level of uncertainty is associated with this score due to the unconfirmed identity of this plant. However, this section will emphasize Kauai-specific information or common traits found amongst species in Section Vetrix in an attempt to minimize this uncertainty. Additionally, two final scores are recommended for consideration based on two taxonomic outcomes: a hybrid (lower score) and a fertile species (higher score).

1. Impact on natural community structure and/or composition

Score: 2 or 3 = Moderate or High impacts, depending on taxonomic ID

Salix sp. was assigned a score of 2 or 3, depending on the final identification of the plant. A minimum score of 2 for a hybrid is appropriate due to their ability to form dense thickets in wetland or riparian ecosystems where they are introduced. The population growing in Waineke swamp is currently forming a large component of the canopy where it has naturalized on Kauai, albeit this area is fairly small at present and apparently restricted to a wetland. *S. cinerea* is a well-studied, serious weed forming dense thickets in wetlands and riverine riparian areas in Australia, New Zealand and

North America, reducing native biodiversity and severely altering ecosystem structure (Giljohann et al. 2011, Hopley and Young 2015, Burge et al. 2017, Griffiths et al. 2017). Land managers and government agencies are investing in the development of aerial, remote sensing and biocontrol tools to manage *S. cinerea* infestations (Adair et al. 2006, Moore and Runge 2012, Griffiths et al. 2017). However, the notoriety of *S. cinerea* as a weed of national significance is likely at least partially due to its distribution, which is facilitated by the spread of wind-dispersed seeds (Hopley and Young 2015). Regardless of seed production, *S. cinerea* is one example of a species within Section Vetrix able to form dense thickets that exclude other plants. *S.* x *reichardtii* is an example of a sterile hyrbid that has managed to naturalize along river banks and lake shores by vegetative means in Australia (PlantNET. 2017). Although it is not considered a weed of national significance in Australia like the seed-producing *S. cinerea*, *S.* x *reichardtii* is still noted as "highly invasive" in the Australian Weeds Committee's strategic action plan for the management of willows (Matthew et al. 2008). Thus, if the identification of the plant is a hybrid, it will likely continue to invade Waineke Swamp which contains native species. As many *Salix* require very moist, marshy or riparian environments, it may be unlikely that this species will spread into the uplands directly next to Waineke swamp. However, *S. cinerea* is able to naturalize in drier habitats relative to other members of the genus (Cremer 2003). As this wetland is connected to a complex of streams and other low-lying areas, *Salix* sp. may use these areas as a corridor for spread. However, this is dependent on the canopy cover in these areas as many Salix prefer open environments (Cremer 2003).

However, if future efforts identify this plant as a seed-producing *Salix*, then a score of 3 is warranted as it is possible that additional populations could establish in suitable habitat elsewhere, as their light parachute-like seeds can disperse long distances by wind (Hopley and Young 2015). These habitats may include Kauai's open bog habitats containing important native and endangered plants. The ability of *Salix* sp. to tolerate high soil acidity in bog habitats on Kauai cannot be inferred, but other *Salix* species have exhibited surprising tolerance to acidic soils (Hammer et al. 2003, Mosseler and Major 2014). However, as *Salix* species are usually native to temperate or cooler ecosystems (Lauron-Moreau et al. 2015), the invasion of *Salix* sp. will likely be restricted to upper elevations on Kauai. The known distribution of *Salix* sp. overlaps with one POPREF polygon containing PEP plants (Kokee-KOK).

2. Impacts to Agriculture, Culture and other Human Systems

Score: 2 = Moderate impacts

Salix sp. received a score of 2 because it may colonize ditches and other waterlogged areas along roadsides. However, *Salix* sp. is unlikely to invade lowlands, limiting its ability to impact to human infrastructure beyond the Kokee area. Many members of the Salicaceae are cited as allergenic (Ranta and Satri 2007), and the pollen of two species within Section Vetrix (*S. caprea* and *S. atrocinerea*) have been confirmed as human allergens (Ferreira et al. 2016, Health 2018). Particularly, *S. caprea* is considered a "severe allergen" and is used in laboratory research projects studying the treatment of human allergic reactions. Hybrid plants, as long as they are male, also produce pollen (Matthew et al. 2008). *Salix* sp. in Kokee was found covered in sooty mold (K. Fiedler, pers. comm) that was apparently being spread by a dense infestation of *Tuberolachnus salignus* (giant willow aphid). This aphid is a new island record for Kauai (Bernard *In press*), and may have been introduced alongside *Salix* sp. found in Kokee, as members within the *Salix* genus are its natural host and no other members have been recorded in Kokee. This aphid has been known to host shift to other plants (although it is unknown how often this happens) (Sopow et al. 2017). As *T. salignus* is the largest aphid in the world, colonies produce copious amounts honeydew that is readily harvested by honey bees. Unfortunately, the honeydew of *T. salignus* contains melezitose sugar, which is not removed by bees and results in the crystallization of honey (Sopow et al. 2017). It is sometimes called "cement honey" if large amounts of melezitose sugar are incorporated, which lowers the value considerably. Thus, *Salix* sp. may facilitate impacts to impact honey bee farms on Kauai by acting as a vector for the aphid, although this is dependent on how widely it is able to naturalize and how readily this aphid is able to host shift to cultivated plants. As *T. salignus* has never been reported elsewhere on Kauai, there is a chance that the removal of *Salix* sp. from Kokee may also eradicate the aphid from the island.

3. Impacts to biotic and abiotic processes

Score: 2 or 3 = Moderate or High impacts, depending on taxonomic ID

Salix sp. should minimally be assigned a score of 2 because many *Salix* species form dense rooting systems in waterlogged or seasonally wet areas (Shafroth et al. 1994, Mosseler and Major 2014). *Salix* are often purposefully planted as a soil stabilizing species, but are capable of significantly altering river and wetland bank structure and habitat for freshwater organisms (Matthew et al. 2008, Hopley and Young 2015, Watts et al. 2016). As *Salix* sp. was observed covered in sooty mold and aphids during field surveys, this species may act as an alternate host for many other plants. For example, *T. salignus* has been observed attacking a native plant, *Osteomeles anthyllidifolia* (ulei), on Maui (Beardsley 1966, 1979). Even if *Salix* sp. is determined to be a sterile hybrid in the future, at least moderate impacts are expected due to its ability to spread through Waineke swamp and connected riverine systems vegetatively. If this species is capable of producing seed, a score of three may be warranted because it may establish along open waterways throughout high elevation areas on Kauai by wind-dispersed seed.

TOTAL INVASIVE IMPACTS SCORE: 6 or 8, depending on taxonomic ID

Feasibility of Control Score

Feasibility of Control Scoring and rationale for *Salix* sp. 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 *Salix* sp. was given a score of 2 because only one location is known. Additionally, many *Salix* species require open areas with inundated soils, and thus, delimiting surveys are not likely to detect additional plants in adjacent upland areas (Matthew et al. 2008). However, surveys of cabin sites should be conducted to determine whether other *Salix* sp. have been cultivated in the area.

Initial control:

Score: 3 = Minimal Effort

Feasibility of initial control for *Salix* sp. was given a score of 3 because control by herbicide (basal bark and foliar application) is known to be an effective control method for other members of the genus *Salix* Section Vetrix (Cremer 2003, Burge et al. 2017, Griffiths et al. 2017).

Monitoring:

Score: 3 = Minor Effort

Feasibility of monitoring for *Salix* sp. was given a score of 3 because even if *Salix* sp. is eventually identified as a seed-producing species, seeds from other species in genus *Salix* Section Vetrix are known to lose viability in the soil after 8 weeks (Cremer 2003, Hopley and Young 2015).

FEASIBILTY OF CONTROL SCORE: 8

COMBINED SCORE= (6 or 8) + 8 = 14 or 16, depending on final taxonomic ID

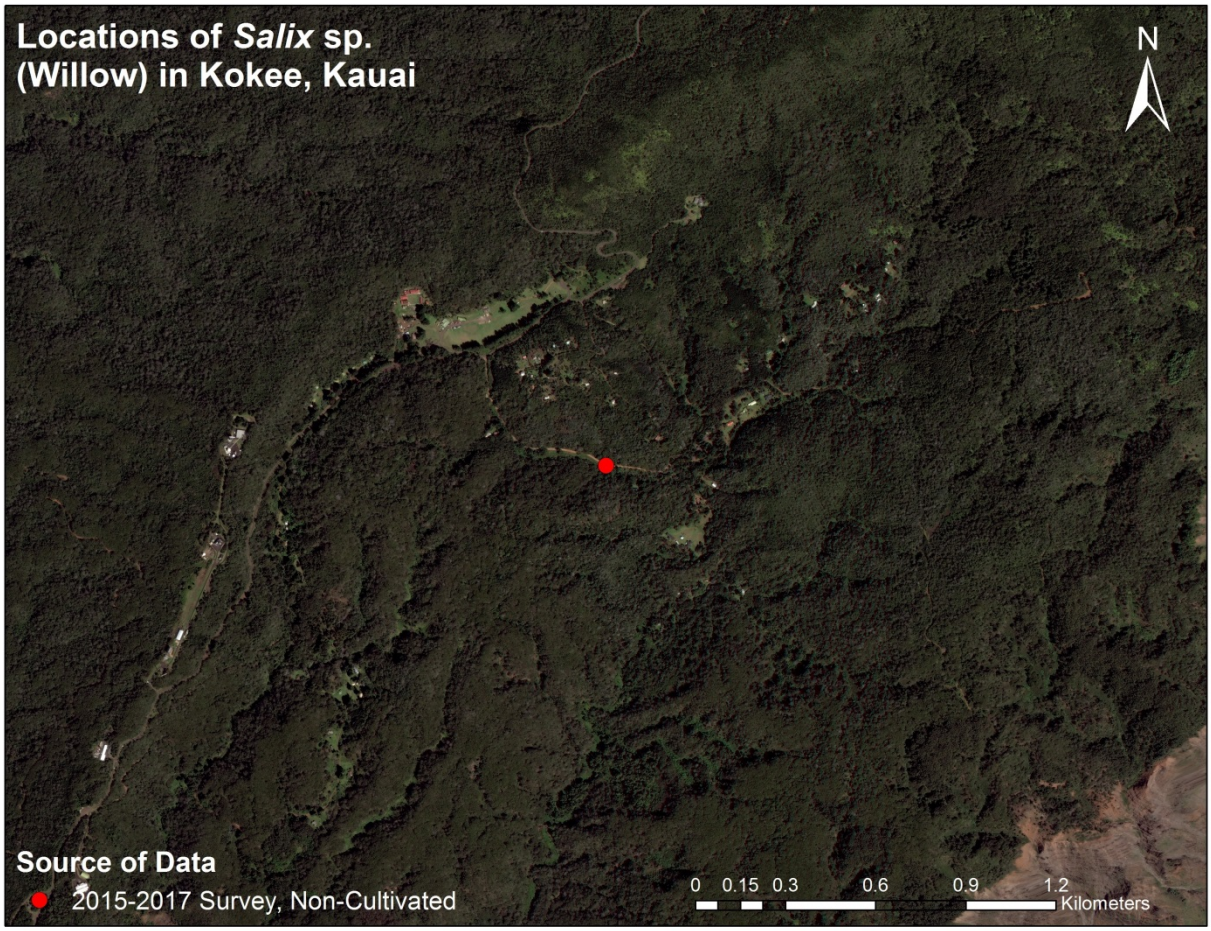

Figure C38- 3. Map of *Salix* sp. in Kokee found during 2015-2017 surveys.

Literature Cited

Adair, R., J. L. Sagliocco, and E. Bruzzese. 2006. Strategies for the biological control of invasive willows (Salix spp.) in Australia. Australian Journal of Entomology **45**:259-267.

Argus, G. W. 2003. Salix. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 20+ vols. Pages 4-157.

Beardsley, J. W. 1966. Notes and Exhibitions: *Tubernolachnus salignus* (Gmelin) a new record for Maui. Proceedings of the Hawaiian Entomological Society **19**:139.

Beardsley, J. W. 1979. The current status of the names of Hawaiian aphids (Homoptera: Aphididae). Proceedings of the Hawaiian Entomological Society **23**:45-50.

Bernard, J. *In press*. New records and range expansions of terrestrial arthropods on Kauai. Bishop Museum Occasional Papers.

Burge, O. R., K. A. Bodmin, B. R. Clarkson, S. Bartlam, C. H. Watts, and C. C. Tanner. 2017. Glyphosate redirects wetland vegetation trajectory following willow invasion. Applied Vegetation Science **20**:620-630.

Chen, J. H., H. Sun, J. Wen, and Y. P. Yang. 2010. Molecular phylogeny of Salix L. (Salicaceae) inferred from three chloroplast datasets and its systematic implications. Taxon **59**:29-37.

Cremer, K. W. 2003. Introduced willows can become invasive pests in Australia. Biodiversity **4**:17-24.

Ferreira, B., H. Ribeiro, M. S. Pereira, A. Cruz, and I. Abreu. 2016. Effects of ozone in Plantago lanceolata and Salix atrocinerea pollen. Aerobiologia **32**:421-430.

Fogelqvist, J., A. V. Verkhozina, A. I. Katyshev, P. Pucholt, C. Dixelius, A. C. Ronnberg-Wastljung, M. Lascoux, and S. Berlin. 2015. Genetic and morphological evidence for introgression between three species of willows. Bmc Evolutionary Biology **15**.

Giljohann, K. M., C. E. Hauser, N. S. G. Williams, and J. L. Moore. 2011. Optimizing invasive species control across space: willow invasion management in the Australian Alps. Journal of Applied Ecology **48**:1286-1294.

Griffiths, J. W., C. J. Howell, and D. Burlace. 2017. Mapping Grey Willow (Salix cinerea) stand architecture using airborne laser scanning: implications for large-scale tree weed control. Ecological Management & Restoration **18**:66-70.
Hammer, D., A. Kayser, and C. Keller. 2003. Phytoextraction of Cd and Zn with Salix viminalis in field trials. Soil Use and Management **19**:187-192.
Health, I. 2018. www.pollenlibrary.com. Goat Willow (Sapix caprea).
Hopley, T., and A. G. Young. 2015. Knowledge of the reproductive ecology of the invasive Salix cinerea, in its invaded range, assists in more targeted management strategies. Australian Journal of Botany **63**:477-483.
HPWRA. 2017. Salix x reichardtii. Hawaii Pacific Weed Risk Assessment.
HPWRA. 2018. Salix cinerea. Hawaii Pacific Weed Risk Assessment.
Imada, C. T. 2012. Hawaiian native and naturalized vascular pland checklist (December 2012 update). , . Bishop Museum Technical Report 60/ Hawaii Biological Survey Contrib. 2012-021: 29 pp. + 27 appendices.
Lauron-Moreau, A., F. E. Pitre, G. W. Argus, M. Labrecque, and L. Brouillet. 2015. Phylogenetic Relationships of American Willows (Salix L., Salicaceae). Plos One **10**.
Matthew, J., A. Vlok, and K. Travis. 2008. Strategic Action Plan for Willows in the North Central Region, Victoria Alluvium and HLA ENSR for North Central Catchment Management Authority
Meikle, R. D. 1992. BRITISH WILLOWS - SOME HYBRIDS AND SOME PROBLEMS. Proceedings of the Royal Society of Edinburgh Section B-Biological Sciences **98**:13-20.
Moore, J. L., and M. C. Runge. 2012. Combining Structured Decision Making and Value-of-Information Analyses to Identify Robust Management Strategies. Conservation Biology **26**:810-820.
Mosseler, A., and J. E. Major. 2014. Coppice growth responses of two North American willows in acidic clay soils on coal mine overburden. Canadian Journal of Plant Science **94**:1269-1279.
PlantNET. 2017. New South Wales Flora Online.
Ranta, H., and P. Satri. 2007. Synchronized inter-annual fluctuation of flowering intensity affects the exposure to allergenic tree pollen in North Europe. Grana **46**:274-284.
Shafroth, P. B., M. L. Scott, J. M. Friedman, and R. D. Laven. 1994. ESTABLISHMENT, SEX STRUCTURE AND BREEDING SYSTEM OF AN EXOTIC RIPARIAN WILLOW, SALIX X RUBENS. American Midland Naturalist **132**:159-172.
Sopow, S. L., T. Jones, I. McIvor, J. A. McLean, and S. M. Pawson. 2017. Potential impacts of Tuberolachnus salignus (giant willow aphid) in New Zealand and options for control. Agricultural and Forest Entomology **19**:225-234.
Watts, C., D. Thornburrow, and V. Cave. 2016. Responses of invertebrates to herbicide in Salix cinerea invaded wetlands: Restoration implications. Ecological Management & Restoration **17**:243-249.