Stakeholder Perceptions: Biological Control of Russian Olive *(Elaeagnus angustifolia)*

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ABSTRACT

An online survey was distributed through email lists provided by various stakeholder groups on behalf of the International Consortium for Biological Control of Russian Olive in spring of 2012. A total of 392 respondents replied from 24 U.S. states and 1 Canadian province. Questions posed in the survey were designed to identify and categorize 1) stakeholders by geographic location, profession and professional affiliation; 2) stakeholder perceptions of Russian olive as a problematic and/or beneficial organism; 3) by ecological, economic and geographic scale stakeholders' perceived benefits and/or detriments associated with Russian olive; and 4) potential benefits and/or risks stakeholders thought might arise from the implementation of a classical biological control program for Russian olive. The survey also asked stakeholders to suggest additional research to improve understanding both of Russian olive and Russian olive biological control. The survey link was widely distributed and respondents were given from February through May 2012 to complete the questionnaire. The questionnaire was highly informative because it included many opportunities for respondents to provide detailed responses in their own words.

Nomenclature: Russian olive, *Elaeagnus angustifolia* L., ELGAN

Key Words: Conflict of interest, survey, weed biocontrol, non-target impacts, wildlife habitat, wildlife resources, shelterbelt, riparian, restoration

INTRODUCTION

The date and location of Russian olive's (*Elaeagnus angustifolia* L.) initial introduction to North America is unknown. Some of the earliest U.S. introductions are anecdotally attributed to German settlers who brought plant material from Russia when they immigrated to South Dakota in the late 1800s (Hansen 1901). Russian olive was highly recommended for planting by a number of western and south western state horticulturalists in the early 20th century (Christensen 1963). Thereafter it was widely planted throughout the west, south west and mid-west as an ornamental and shade tree, in windbreaks, for erosion control, and more recently, for wildlife habitat enhancement and as a nectar source for honey bees (Olson and Knopf 1986; Zouhar 2005). Escape from cultivation, a highly likely consequence of Russian olive's popularity and utility, was first reported in 1924 (Christensen 1963). Russian olive is now estimated to be the fifth most abundant riparian

plant species in the western United States (Friedman et al. 2005), and is considered naturalized in at least 17 U.S. states (Olson and Knopf 1986) and five Canadian provinces (Katz and Shafroth 2003).

Russian olive has spread and become locally dominant to the extent that its negative economic and environmental impacts frequently outweigh its benefits. Russian olive poses a significant threat to biodiversity on western North American floodplains, and could eventually dominate Montana's Milk River and Marias River floodplain ecosystems to fully replace plains cottonwood (*Populus deltoides* Marsh.) within the 21st century (Pearce and Smith 2001; Lesica and Miles 1999). As a N_2-fixing species, Russian olive potentially functions as a so-called 'transformer' invasive species (D'Antonio et al. 2004) due to its ability to alter both terrestrial and benthic nutrient and community dynamics in invaded riparian areas (Mineau et al. 2012, -2011; Shah et al. 2010; Reynolds and Cooper 2010). Indirect effects of Russian olive, such as the intensification of beaver attack on increasingly reduced stands of native tree species, can alter riparian vegetation community structure and composition (Lesica and Miles 2004).

Few native tree species survive and thrive as well as Russian olive under the harsh growing conditions of the northern Great Plains (Stannard et al. 2002). In this geographical region, Russian olive is commonly viewed as a highly desirable and beneficial tree, and seldom considered to be an invasive noxious weed. Even so, negative impacts on Montana agricultural production necessitated the investment of more than $600,000 in Russian olive control projects between 2005 and 2007 (Montana Audubon 2010). As an example of polarization of attitudes toward Russian olive, on August 2, 2009 the *Billings Gazette* ran two articles under the headlines: "State asked to balance benefits, drawbacks of Russian olives," and, "A weed or wonder? Non-native Russian olive trees a nuisance to some, saviour to others" (http://billingsgazette.com/news/state-and-regional/montana/state-asked-to-balance-benefits-drawbacks-of-russian-olives/article_005cf908-7f0b-11de-bffe-001cc4c03286.html).

Conflicts of interest associated with the proposed regulation of non-native plant species are not unique to Russian olive (Stanley and Fowler 2004; Turner 1985). Benefits vs. costs of woody invaders such as acacia (*Acacia* spp.) (Dodet and Collet 2012; de Wit et al. 2001; Higgins et al. 1997) and tamarisk (*Tamarix* spp.) (Dudley and Bean 2012) continue to be hotly debated. Research conducted to develop management recommendations for invasive weeds is costly. Therefore, it is essential to determine early on whether the intended management target is viable in terms of stakeholders' perceived need for development of species-specific control methods, including classical biological control (de Wit et al. 2001; Higgins et al. 1997). A lack of communication among groups involved in or affected by weed management programs may lead to conflicts of interest and mistrust (Kapler et al. 2012; Wilson et al. 2011).

Classical biological control can be a sustainable, long-term approach for managing well established, widely distributed exotic invasive weeds such as Russian olive (McFadyen 1998). High selectivity and low risk of nontarget impacts further recommend biological control in ecologically sensitive and regulatory challenging riparian areas where Russian olive typically occurs. However, the movement and impact of biological control agents does not end at political or habitat boundaries, making their release unconstrained except by environmental and ecological restrictions, and therefore practicably irreversible. As an example, agents applauded for effectively controlling Russian olives clogging irrigation canals and bottomland pastures would not be welcomed to attack shelterbelt or ornamental trees. Any management program against Russian olive, including biological control, should therefore consider potential conflicts of interests of Russian olive as both an invasive and a beneficial species.

Foreign exploration and preliminary overseas screening of candidate agents for the present Russian olive biological control program, initiated in 2007, is being led by CABI Europe-Switzerland under the direction of the International Consortium for Biological Control of Russian Olive. Start-up funding provided by the Consortium's continually growing U.S. and Canadian membership has been used by CABI-

Europe to conduct literature and field surveys for potential biological control agents in the weed's native range, to experimentally increase knowledge about potential agents' basic biology and ecology, to conduct preliminary impact and host specificity assessments, and from those results, to produce a priority list of candidate agents (Schaffner et al. 2012).
Based on field surveys conducted between 2007 and 2015, and information obtained from taxonomists and through associated literature, a number of biological control candidates have been prioritized for live collection and in-depth studies. The search for candidate agents has deliberately focused on herbivores that impede the unchecked reproduction of Russian olive by disrupting the normal development of the fruit, shoots and flowers. This tactic was adopted to intentionally protect valued existing trees while holding the spread of unmanaged Russian olive plants in check. As a precedent, selection of site-specific (e.g., seed feeders vs. root feeders), non-lethal biological control agents was proposed as a viable compromise between management and stakeholder needs (or demands) for resources provided by black wattle (*Acacia* sp.; de Wit et al. 2001).

Perhaps more importantly, though, understanding and responding strategically to stakeholder concerns regarding planned biological control of Russian olive would significantly increase the feasibility and success of a future biocontrol program.

One activity conducted on behalf of the international Russian olive biological control consortium was to send out an electronic survey to solicit stakeholder and researcher feedback about Russian olive as a noxious weed and/or beneficial tree, desires to manage or conserve this tree, concerns about using biocontrol as a tool to manage Russian olive, other research concerns/gaps that need to be addressed prior to Russian olive management (esp. by classical biocontrol agents), and whether individuals would be interested in attending a conference to discuss aspects of Russian olive as a conflict species and whether biocontrol is a viable management option. The survey proved to be a useful starting point to assess stakeholder feedback about Russian olive and biocontrol, and to initiate dialogue during a USDA NIFA AFRI sponsored symposium held February 10-11, 2013 in Spokane, WA.

RESULTS

Respondent demographics:

The survey was completed by respondents located in the following Canadian province and U.S. states (n=392; number of respondents following province/state name): Alberta (Canada) – 1; Arizona – 7; Arizona, New Mexico and Utah – 1; California – 1; Colorado – 67; Colorado, New Mexico, Utah – 1; Idaho – 18; Illinois – 2; Kansas – 4; Maryland – 1; Missouri – 2; Montana – 173; Montana and Wyoming – 1; 'national' – 1; North Dakota – 4; Nebraska – 3; New Mexico – 7; New Mexico and Louisiana – 1; Nevada – 6; Oklahoma – 3; Oregon – 8; Pennsylvania – 1; South Dakota – 8; Texas – 1; Utah – 35; Washington – 4; Wisconsin – 1; West Virginia – 1; Wyoming – 27; and Wyoming, Montana, South Dakota and North Dakota - 1. Respondents self-identified according to non-mutually exclusive stakeholder categories (*n*=405) most frequently as 'federal government' (31.4%), followed by 'landowner' (25.4%), 'state government' (22.5%), 'county government' (22.5%), 'other' (12.4%), 'non-profit agency' (8.6%), 'college/university' (7.9%), 'town government' (3.2%), 'industry' (2.7%), and 'Native American tribe' (2.7%). Respondents provided the name and location of their group, agency or organization (not listed here), and indicated (*n*=371) that the activity or activities their group performed fell into the following broad, non-mutually exclusive categories: 'land management' (84.6%), 'education' (62.5%), 'research' (32.3%), fundraising' (9.2%), 'lobbying' (5.4%), 'hunting' (20.2%), or 'other' (19.9%). The region of interest of the respondents' group,

agency or organization was county - 30.5%; statewide -22. 6%; specified area within a state - 19.8%; region within the U.S. - 18.8%; national - 4.9%; tribal lands - 1.9%; and city - 1.6%.

Respondents' perceptions of Russian olive as a weedy and/or beneficial plant:

Russian olive was believed by survey respondents to have escaped cultivation at the city/town scale by 67.6%, and at county or state scales by 85.4% and 94.4%, respectively. Russian olive was considered to be an invasive plant by 73.1% of respondents (*n*=379) at regional - 40.9%, state - 40.2%, county - 35.9% and/or town - 10.7% geographic scales. Respondents considered the following habitats to be negatively affected by the presence of Russian olive: riparian - 65.2%, wetland - 10.1%, pasture/rangeland - 9.4%, waterways - 6.5%, uplands - 5.4%, meadows/old fields - 5.1%, all habitats - 4.4%, and irrigated fields - 4.0%. The severity of Russian olive invasions was categorized by respondents (*n*=300) as high - 31.3%, medium - 45.7%, low - 18.0%, none - 2.0%, and don't know - 3.0%. Respondents described Russian olive as an invasive species according to its negative impacts on the following broad categories (limited here to the ten categories receiving the highest number of responses): native plants - 62.8%; habitat – 21.5%; water - 17.1%; wildlife - 14.8%; agriculture - 13.8%; access – 12.8%; none – 11.1%; hydrological – 8.1%; infrastructure – 5.4%; and recreation – 5.0%. Negative cultural impacts due to Russian olive as an invasive species were identified by only 3 respondents, which could easily cause the importance of access to and use of cultural sites and resources to be under-estimated if a numerical assessment of responses only was being considered.

Russian olive was overall considered to be a beneficial species by 52.8% of respondents (*n*=371) at regional – 27.4% (vs. invasive at 40.9%); state – 25.9% (vs. invasive at 40.2%); county – 41.1% (vs. invasive at 35.9%); and town – 12.2% (vs. invasive at 10.7%) geographic scales. Respondents considered the following habitats to be benefited by the presence of Russian olive: uplands – 31.5% (vs. harmed at 5.4%), riparian – 24.4% (vs. harmed at 65.2%), shelterbelts – 20.8%, dryland – 13.7%, windbreaks – 9.6%, ornamental – 8.1%, wildlife – 8.6%, and pasture/rangeland – 5.1% (vs. harmed at 9.4%). Respondents who considered Russian olive to be a beneficial species in their area ranked the usefulness of Russian olive benefits (*n*=224) as high - 39.3%, medium - 36.6%, low - 15.6%, none - 6.3%, and don't know - 2.2%. Write-in responses listed positive impacts due to Russian olive as a beneficial species in the following broad categories (limited here to the ten categories receiving the highest number of responses): bird/wildlife habitat – 72.4%; wildlife food – 46.9%; wildlife shelter/cover – 44.9%; shade/windbreak/shelterbelt – 42.1%; bird food – 40.2%; bird shelter/cover – 30.7%; ornamental – 20.5%; erosion control/bank stability – 16.5%; livestock shelter/cover – 9.4%; and none – 4.3%. Notable Russian olive benefits identified by respondents included nitrogen fixer (1.2%); nectar/pollen/honey (0.8%); carbon storage (0.4%); medicinal (0.4%); and discourages transient camps (0.4%). Respondents ranked the importance of the positive impacts of Russian olive (values for importance of negative impacts by rank provided for comparison) as high - 33.5% (vs. 46.5%); medium – 30.9% (vs. 29.7%); low – 22.8% (vs. 14.1%); none – 10.3% (vs. 6.0%); and don't know – 2.6% (vs. 3.6%).

Respondents' concerns about existing management options for Russian olive:

Write-in responses to the question, "what concerns do you have regarding existing management options for Russian olive control" were broadly categorized as cost – 23.0%; no consensus on the need for control – 21.7%; negative habitat impacts (of control methods) – 15.1%; none (no concerns) – 12.6%; unsustainable – 10.4%; approach/methods of control – 10.1%; lack of coordination of control programs – 9.4%; labor – 7.9%; efficacy – 7.2%; and spread - 5.7%.

Respondents' concerns regarding biological control of Russian olive:

With regard to biological control of Russian olive, 52.8% of respondents indicated that they had concerns, 33.4% were not concerned and 13.8% did not know if they were or should be concerned. Write-in responses

addressing concerns about a defoliating biocontrol agent included potential for nontarget impacts - 42.7%; control not selective (would target both invasive and desired Russian olive trees) - 16.6%; potential negative impacts on wildlife/birds - 12.3%; agent, efficacy unpredictable - 11.4%; unwanted attack on shelterbelts/windbreaks - 10.4%; negative ecosystem impacts - 5.7%; generation and issues about the disposal of woody debris - 5.2%; feeling of being forced to control Russian olive - 3.8%; unwanted attack on ornamentals - 2.4%; and waste of money - 1.9%.

The top ten write-in responses regarding respondents' concerns about the use of a biocontrol agent that could actually kill Russian olive trees included many of the same categories: potential for nontarget impacts - 30.8%; control not selective - 18.2%; negative impacts on shelterbelts/windbreaks - 9.6%; deleterious effects on wildlife/birds - 9.1%; woody debris – 9.1%; none – 6.1%; potential to increase or encourage other invasive weed species – 3.5%; feeling that control was not needed – 3.5%; and potential for unacceptable harm to ornamental Russian olive trees – 2.5%.

Top five concerns about the use of a fruit/seed targeting biocontrol agent were: potential for nontarget impacts - 33.9%; none (no concerns over the use of a fruit feeder) - 27.4%; negative impacts of wildlife /birds - 20.2%; concerns that the agent or its efficacy will be unpredictable or inadequate - 11.3%; and concerns about control not being selective in terms of trees attacked (e.g., invasive vs. ornamental Russian olive) - 5.4%. Many write-in responses focused on the lack of information on the nutritional value and overall importance of Russian olive fruits for organisms at multiple trophic levels: arthropods, birds, and small vertebrates to large ungulate mammalian wildlife. One respondent suggested that stand replacement testing should take place to determine if species replacing Russian olive under natural succession following successful biological control would be acceptable or not as a food source for wildlife species now considered dependent on Russian olive fruits.

Respondents wrote in a number of other concerns about biological control of Russian olive and its potential impacts. The greatest number of responses (39.5%) specified concerns about potential non-target impacts. The next highest concern (16.0% of respondents) was about making biological control of Russian olive more selective in terms of the location of treatments, specifically, how to ensure that agents would be retained on stands of invasive trees targeted for control in riparian areas, reservoirs and irrigation ditches, and not randomly moving into upland bird habitat, ornamental or shelterbelt trees. Concerns about biocontrol impacts on bird and wildlife habitat quality, and potential issues with vegetation restoration and succession following biocontrol of Russian olive were cited at the same level, 8.3%. 15.3% of respondents had no concerns about potential impacts of biological control, while 10.6% felt that biological control options simply were not needed. One respondent felt that biological control of Russian olive should be studied in concert with saltcedar biocontrol. Another reported that in his/her experience, biocontrol agents tended to work best in upland sites, where Russian olive is considered an effective habitat component, but pointed out that biocontrol would be most valuable if it targeted trees invading moist habitats/shaded environments. One respondent, perhaps annually besieged by box elder bugs, voiced a legitimate concern that the Russian olive agents might also move to structures (houses) to over-winter. One respondent addressed in detail the potential economic impacts a Russian olive biological control program might have on upland game bird production and survival:

> "Please consider the economic impact to upland game bird production and survival. Hunters spend millions of dollars annually in pursuit of upland game birds in Montana. The Plentywood area in northeastern Montana lacks quality winter cover. Periodic severe winter conditions, in a region lacking quality winter cover, suffer high mortality losses. Local restaurants, gas stations and motels experience the loss of revenue generated by reduced hunter traffic following tough winters.

We have significant documentation to show high pheasant and sharptailed grouse survival rates in locales containing Russian olive thickets or shelterbelts containing Russian olive."

Respondents' suggestions for additional research:

Respondents were asked to write in suggestions for additional research 1) needed on biological control of Russian olive, such as studies on wildlife impacts, consequences of fruit reduction, possible impacts on endangered species, etc.; 2) to better understand Russian olive in their area, or nation-wide; and 3) any other research suggestions related to Russian olive.

In response to the question "Can you suggest any additional research needed on biocontrol of Russian olive, such as studies on wildlife impacts, consequences of fruit reduction, possible impacts on endangered species, etc.?", 67.6% of respondents indicated that additional research was needed but not all specified the type of information they felt was lacking or unavailable. 23.7% of respondents indicated that no further research was required; 1.7% did not know if information was lacking; and 4.0% were opposed to all aspects of Russian olive biological control, including further research (*n*=173). Few of the write-in responses to this survey question actually suggested studies that would clarify issues directly related to biological control. Most instead indicated a critical need to better understand and assess the value of Russian olive's ecological and economic contributions to western and southwestern shrubland.

The majority of suggestions for additional research on biocontrol of Russian olive addressed concerns about the value of Russian olive as a resource for wildlife (36.4%). Respondents wanted to know which wildlife species currently utilize Russian olive, which species have become dependent on the resources it provides, and why species have become dependent on resources provided by this relatively recent invader. Multiple respondents prioritized the need for quantitative documentation on the quality of basic wildlife resources, such as food and shelter, provided by Russian olive. Data gaps identified included nutritional and energetic analyses of Russian olive's overall contribution to the diets of resident and migratory wildlife, and specifically to stored fat reserves essential to successful migration or over-wintering; percentage of game (bird and animal) foraging conducted in Russian olive stands, broken down by season; and dependence of game and livestock on Russian olive for fawning/calving cover. The possibility that Russian olive was driving and therefore probably altering avian and other species distributions was raised.

215 respondents wrote in answers to the question "Can you suggest any research which needs to be conducted to better understand Russian olive in your area or nation-wide?"; 'no' was the most frequent response (19.1%). The second most frequent category of response addressed the need to better understand the type and quality of resources provided by Russian olive to livestock and wildlife, including birds (18.6%). Objective comparisons of nutrition and shelter provided by Russian olive vs. native tree or shrub species were specifically requested, as in this example: "I would like to know the wildlife preferences in associations of hawthorne and silver buffaloberry in shallow water table areas". Another respondent wanted to know if variability in other ecosystem attributes was driving localized increases or decreases in wildlife utilization of Russian olive: "Is there a difference between wildlife utilization of (Russian olive) depending on what area of the country? For example, in areas where resources are more limited, is (Russian olive) acting more 'beneficial?'".

Risk: benefit or cost: benefit analyses as a way to objectively weigh the ecological or economic costs against the benefits of Russian olive control or removal were suggested by 9.8% of respondents. 8.8% of responses addressed the need for further research to better understand how Russian olive infestations impact floral and faunal biodiversity. 8.4% of responses called for further research to identify factors predictive of Russian olive infestation. Many respondents had specific questions about succession or

restoration of the vegetation community following Russian olive control or removal (7.9%). The same percentage of responses (7.9%) addressed the need for additional research on the distribution and spread of Russian olive. 6.5% of responses suggested that additional research was required to understand how to selectively target biocontrol to areas where Russian olive is considered invasive, and that further unspecified biocontrol-related research was required. Four categories of further research were suggested in the same percentage of responses (5.6%): general impacts of Russian olive infestations; Russian olive biology/ecology; breeding programs to produce sterile or non-invasive Russian olive or suggestions for alternative plants for ornamentals, shelterbelts and bird/wildlife food and habitat; and improving conventional or integrated control of Russian olive.

Write-in responses for other research suggestions related to Russian olive (*n*=124) listed 'no' as the most frequent response (43.5%). Ecological studies to assess both positive and negative impacts of Russian olive were listed as the second most frequent broad category of suggestions for further research (14.5%). Suggestions for additional ecological research focused on water use and hydrological themes would investigate the potential for Russian olive to lower the water table and thereby help control saline seep; Russian olive water uptake potential and how it can alter hydrology; assessing water use by Russian olive in riparian areas and impacts Russian olive water use has on other species and on creek flow; comparing river management (stage height level and duration) to Russian olive establishment levels; timeline of watershed infestation by Russian olive; and how flooding inundation affects Russian olive, and duration of inundation required to impact Russian olive. Suggestions for additional ecological research on vegetation and soil focused topics included the potential use of beneficial trees or shrubs to crowd out Russian olive; community interactions among plant guilds and how they might be affected by allelopathic root exudates of Russian olive; determine the level to which Russian olive (soil) bacterial symbionts fix atmospheric nitrogen in the native and invaded range; changes in soil and water temperatures, aquatic invertebrate as well as vertebrate populations around Russian olive stands; influence of Russian olive on changes in soil pH; and length of time required for dead standing trees to decay.

Additional research on alternatives to Russian olive was suggested by 10.5% of respondents, and included identifying native plant alternatives, or developing sterile or fruitless varieties Russian olive, and less invasive or sterile hybrids of Russian olive, such as the Silverscape® olive (hybrids of Russian olive and silverberry). One respondent suggested research to identify a Russian olive variety that was more palatable to beavers, then using it to cross-breed into zones where invasive varieties currently dominate so beavers could be used as biological control agents. A related but significantly more ambitious research suggestion involved breeding a special strain of beavers "that will eat the stuff".

Responses suggesting studies broadly concerned with better understanding the post-removal environment (7.3%) included research to assess post-removal changes in flora and faunal biodiversity; changes in soil structure and/or nutrient load occur where Russian olive formed monocultures, and these might impede re-vegetation efforts; (a priori) establishment of funding, policies and implementation plans to ensure re-vegetation with native plants to counteract reductions in fruit/pollen resources following Russian olive removal; potential widespread impacts on stream bank stabilization following large scale Russian olive removal; determining how quickly native species respond to Russian olive removal from riparian habitats; and possible uses of and options for dealing with Russian olive biomass generated through removal or control efforts.

6.5% of respondents suggested additional research focused on developing recommendations for Russian olive control or management recommendations, including: suggestions for reasonable (levels of) control rather than eradication; developing recommendations for buffers around riparian areas to prevent invasion of Russian olive from upland shelter belts, to preserve shelter belts and prioritize areas for control

or eradication; options for mechanical control; (comparison of) successes of different methods of Russian olive control; development of selective herbicides – "investing in research and development of herbicides that are species specific"; "what can be done to prevent the spread of the tree"; developing innovative management prescriptions such as using a root-collar damaging technique that works well without pesticide; "attack the root system to reduce seed production by lowering the plant vigor"; methods to reduce/eliminate Russian olive stands where it has become invasive; timing of mechanical cutting, possibly in conjunction with a herbicide treatment; and developing best management practices for Russian olive removal.

SUMMARY

Survey responses uniquely confirmed in the respondents' own words how readily conflict arises when plans to control Russian olive are discussed. Benefits of Russian olive provided to those who dwell and farm or ranch on the northern Great Plains, in terms of upland shelterbelts, erosion control and shade or ornamental trees, are indisputable. However, in riparian areas, wetlands and irrigation canals where it not moisture-limited, Russian olive can become highly invasive and competitive, displacing desirable native species and often forming impenetrable, persistent monocultures.

Dense infestations of Russian olive in moist habitats incur unacceptable losses of both surface and sub-surface water and block access to valuable streamside habitat, watering and recreational sites for native or desirable plant species (e.g., cottonwood), livestock, wildlife and people. Forfeited environmental resources combined with the exorbitant cost of conventional control suggested that a management approach focused on stemming the unchecked reproduction and spread of Russian olive without harming valued upland trees would provide an acceptable compromise. However, survey responses indicated that all forms of biological control presented some level of threat to upland ornamental, shade and shelterbelt trees due to the agents' unrestricted movement.

Respondents suggested that more information was needed on potential impacts to wildlife under various outcomes of Russian olive biological control. Although no conclusive data currently exists on the nutritional value of Russian olive drupes ('olives' or fruits) to wildlife, survey write-in responses conveyed a nearly universal belief that the fruits are a valuable and important food resource for game birds and animals. Respondents were reticent to give unqualified support to biocontrol specifically targeting Russian olive fruits. Numerous suggestions were made about the possibility of using selective breeding to produce trees with infertile drupes in order to reduce invasiveness while retaining fruit production benefits for wildlife.

Projecting into a future where biological or other control may cause Russian olive to become locally or regionally extirpated, respondents identified two critical needs, to fully understand 1) how to facilitate the successful establishment of native alternatives to Russian olive, and 2) the nutritional value, accessibility and preferences of wildlife and livestock for fruits born by native plants as compared to those provided by Russian olive. Respondents sought assurances that native plant species or sterile varieties of Russian olive could reliably provide the same key resources to wildlife currently supplied by invasive, fertile-fruited Russian olive (equivalent host suitability). Respondents were concerned about how readily species adapted to using Russian olive resources could or would successfully switch to obtaining food and shelter from alternative hosts (equivalent host acceptance). A study to compare the number and variety of wildlife species using similar habitats with, and without Russian olive was suggested to identify important indirect interactions following removal.

Specific concerns were conveyed about potential deleterious impacts of Russian olive removal from riparian/wetland areas inhabited by endangered species such as yellow-billed cuckoo or southwestern willow flycatcher. Respondents questioned whether species relying on Russian olive as a sub-canopy layer for

foraging habitat would return to treated areas once native riparian shrubs and trees re-established. Support and maintenance of wildlife, including birds, in areas targeted for Russian olive control was directly linked by many respondents to successful restoration. The importance of planning and research to develop practical restoration recommendations was repeatedly emphasized.

Respondents' greatest concern about Russian olive biological control was the perceived potential for non-target impacts, highest for defoliating agents (42.7% of respondents), followed by agents that could kill whole trees (38.8%), then fruit/seed reducers (33.9%). These responses reflect a prevailing misconception about weed biological control agents: that their behavior is unpredictable, particularly in response to a scarcity or lack of host plants, putting non-targets such as ornamental and crop plants at high risk of attack (Delfosse 2005; Pemberton 2004; Hoddle 2003).

Additional research and outreach could address the majority of concerns and sources of conflict identified through this survey. These efforts should begin by dispelling the most pervasive misconception about weed biological control, that the risk of non-target attack is very high. The results of a recent meta-analysis of intentionally introduced weed biological control agents found that globally, >99% of agents released have had no known significant adverse impacts on non-target plants (Suckling and Sforza 2014).

Pesticides and baits, proven effective respectively for excluding or concentrating biological control agents in other agent-weed systems, could be used to protect upland trees and focus attack on invasive bottomland stands of Russian olive. Feeding studies to assess the nutritional value of Russian olive for game birds and animals would objectively confirm or refute claims that it is an essential high quality food source. Considerable additional research will be required to assess the quality of wildlife resources provided by native alternatives to Russian olive, once protocols for successful restoration have been identified. Overall, prospects for biological control of Russian olive are positive because research and outreach can realistically address concerns disclosed through this survey.

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