SOCIAL DIMENSIONS OF INVASIVE PLANT MANAGEMENT:

AN ALASKA CASE STUDY

By

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Abstract

Uncertainty pervades attempts to identify an efficient management response to the threat of invasive plants. Sources of uncertainty include the paucity of data, measurement errors, variable invasiveness, and unpredictable impacts of the control methods. Rather than relying on this uncertain evidence from the natural sciences, land managers are taking a more participatory approach to invasive plant management to help alleviate risk and share the responsibility of implementation of proactive control and eradication strategies. This research is intended to contribute to this process of social learning by revealing the beliefs that determine stakeholder management preferences in a case study involving an infestation of *Vicia cracca* (bird vetch) affecting public lands, north of the Arctic Circle, along the Dalton Highway in Alaska. Possible encroachment of this "highly invasive" species upon vulnerable areas of high conservation significance in this rapidly changing, boreal-arctic system has motivated some stakeholders to advocate an aggressive, early response aimed at eradication using herbicides. This case study applies social-psychological theory in the study of the interactions between human behavior and human outcomes. Interior Alaska stakeholders were engaged in a survey to measure support for a scenario involving the use of herbicides to control the highly-invasive species, *Vicia cracca* (bird vetch), which has spread north along a road corridor north of the Arctic Circle. Respondents were asked a series of questions about the "likelihood" and "acceptability" of the possible outcomes. The survey results aligned with the expectation that attitudes predict management preference, however the beliefs that influence these attitudes were more complicated than expected. The results address the feedbacks anticipated between the human outcomes and human behavior in the social template within the broader system context that are critical to management success. The purpose is to utilize the results of this specific case study to facilitate the development of ongoing research questions that are generalizable to other affected boreal-arctic ecosystems, regionally and globally.

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Chapter 1: Introduction

Invasive plants represent a perplexing societal dilemma and the decision to respond to their introduction and spread can have far-reaching consequences at multiple scales (Miller & Schelhas, 2008). On a global scale, invasive plants are considered a major driver of biodiversity loss and their tendency to cause catastrophic changes in community structure and ecological function is well-documented (Millennium Ecosystem Assessment, 2005). But, as compelling as this rationale for aggressive control may be, the consequences of management action or inaction are much less transparent when formulating a strategy to control specific infestations at the local level. The problem lies with the over generalization of impacts across scales, which is evidenced by the adoption of eradication as a normative goal. Too often local conservation objectives are motivated by the belief that aggressive control is an imperative despite scarce data to illustrate that it is either economically or environmentally optimal (Eiswerth & Kooten, 2002; Evans, Wilkie & Burkhardt, 2008).

At the core of this dilemma is the uncertainty that pervades attempts to find efficient responses to the threat of invasive plants. Sources of uncertainty include the paucity of data, measurement errors, invasiveness levels, and unpredictable impacts of the control methods. Such uncertainty can be difficult to communicate to stakeholders and can lead to conflicting attitudes and beliefs. To improve communication about complexity and uncertainty, researchers have suggested that stakeholders be engaged in open exchange with managers prior to the implementation of a control program to reduce conflict and increase awareness (Fischer, Selge, van der Wal, & Larson, 2014). This way managers can mitigate conflict proactively and increase the chances of success by avoiding excess impact and control costs that tend to rise exponentially with the size of the infestation (Rejmanek & Pitcairn, 2002; Radosevich, 2002, cited in Spellman & Swenson, 2012).

Incorporating stakeholder beliefs, with an emphasis on social learning and raising awareness of alternative views of a problem, has been effective for coping with such complex uncertainty (Cundill, Cumming, Biggs & Fabricius, 2012). This process of social learning can help generate stakeholder input through a participatory approach where the outcomes are used to guide research and practice. For instance, the formation of knowledge networks (e.g., Committee for Noxious and Invasive Pests Management in Alaska [CNIPM]) can promote social learning by linking stakeholders, land managers, scientists, policy makers and interest groups at multiple scales (Miller & Schelhas, 2008). Other social processes specific to invasive plant management range from formal collaborations such as a Cooperative Weed Management Area (CWMA), to less formal methods of engaging the public (e.g., weed pull events). These forms of engagement help managers better understand the complex attitudes and beliefs that often influence stakeholder management preferences which can result in unnecessary delays due to public opposition (Selge, Fischer & van der Wal, 2011).

This study surveys plausible candidates for participation in the social learning and serves as a precursor to this process. It explores the cognitive behavioral determinants of stakeholder management preferences in a case study focused on the newly-invaded public lands of the boreal-arctic region of Alaska. Attitudes (i.e., a set of beliefs about an object or event) toward the control of one invasive plant species, *Vicia cracca* (bird vetch), using herbicides (*chlopyralid*) were assumed to be based on salient beliefs that ultimately influence management preferences. This research is important because public attitudes toward biodiversity and conservation management are poorly understood (Fischer & van der Wal, 2007), particularly as they relate to invasive plant management. Through improved understanding, managers can better anticipate conflict, build awareness and break down barriers to communication that may impede a timely response (Schwaller, 2001).

To further augment the social learning process, this study concludes by advancing a framework to integrate the findings of this research into an ongoing, interdisciplinary research agenda. Most invasive plant management research in the social sciences has focused on social, economic, and political systems in isolation from their biophysical surroundings. Instead, this research puts emphasis on the issues that arise at the disciplinary boundaries by using the “Press-Pulse Dynamics” (PPD) framework (Collins et al., 2011).

Social-Ecological System Dynamics

Press-Pulse Dynamics framework

The PPD framework bridges the social and natural science domains to steer the production of knowledge to address complex environmental challenges (Figure 1.1). This iterative framework assumes a continuous cycle of human decision and is applied here to articulate the relationship between the biophysical and social templates through sudden events (i.e., pulses) and extensive, pervasive and subtle change (i.e., presses) and the resulting changes in the quantity or quality of selected ecosystem services. The right-hand side, the biophysical template, represents the domain of traditional ecological research, while the left-hand side, the social template, represents the human dimensions of the problem.

There are several instances where the PPD model has been a valuable tool for managing complex systems (e.g., Gardner et al., 2013). In this case, the PPD model has been scaled down here to (1) conceptualize the feedbacks and interacting effects between human decision-making and ecosystem change and (2) encourage an interdisciplinary approach to forming hypotheses related to management decisions that involve invasive plants. The intent is to identify gaps in the understanding as it relates to stakeholder beliefs to guide ongoing research needs that can help reduce uncertainty.

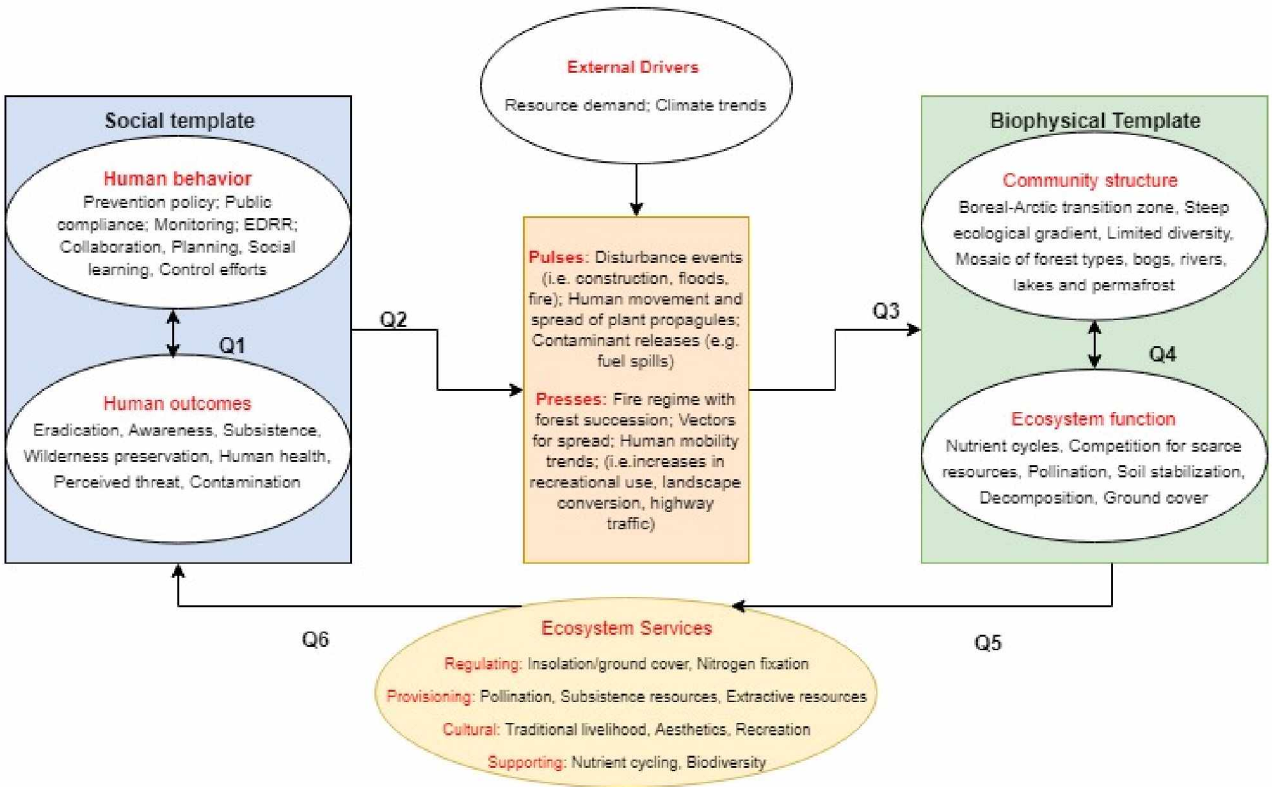

Figure 1.1 The Press Pulse Dynamics framework (Collins et al., 2011) for the Dalton case study illustrates the complexity of multiple concurrent impacts of disturbances in a social-ecological system. Questions (Q1) through (Q6) refer to integrating questions that stem from the interactions.

The PPD model is applied in this case to study the linkages and feedbacks between large-scale land use changes (e.g., oil development, vegetation changes changing fire regimes) and ecological changes on areas of high conservation significance. The intent is to help find a way to harmonize disciplinary perspectives and build capacity for sustainable management of the emerging trends, dynamics, feedbacks and surprises. The goal is to promote a more nuanced understanding of the dynamic structure and interactions of the social–ecological system that is affected by the growing invasive plant problem in this vulnerable region.

Dalton case study

Invasive plants are complex drivers of environmental change that are now encroaching upon relatively intact boreal-arctic ecosystems of Alaska (Carlson & Shepherd, 2007). The vegetative composition and patterns of distribution in the region have remained relatively stable for the past 5000 years. Any movement or introduction of non-native species occurred slowly through trade and natural range expansion. Historically, these slow rates of movement have allowed for adaptation and naturalization (Chapin et al., 2006). In recent decades, rapid social-ecological change has increased rates of introduction and spread of non-native plants into the area that threaten to disrupt the flow of ecosystem services. Although the problem is in the early stages, the susceptibility of the region to the impacts of invasive plants is increasing with changes in climate and patterns of human use, particularly from the neighboring sub-arctic zone (Lassuy & Lewis, 2013).

Today, the Dalton Highway is the only north-south corridor that transects this large, extremely remote and very sparsely populated region (Figure 2.2). The Dalton Highway was built in 1974 as an industrial haul road to access the Prudhoe Bay oilfields near the Arctic Ocean. The roadway roughly parallels the Alyeska Pipeline and was restricted from public access until 1994 when it was opened for public access to tourism, recreation and research. It is maintained by the State of Alaska Department of Transportation and crosses the Central Yukon Region (CYR), which is federal public land under the jurisdiction of the Bureau of Land Management (BLM). The CYR planning area shares boundaries with an array of neighbors including four boroughs, 24 remote villages, 15 tribal entities, 6 federal land management units and three Alaska Native Claims Settlement Act (ANCSA) corporations.

Despite its remote and extreme environment, the region draws significant state and national attention to management decisions about natural resources on public lands because it has a central role in future development (e.g., oil and gas, tourism) and is experiencing the impacts of climate change on a magnitude much greater than other regions of Alaska. Changes in climate and human activity make the region increasingly vulnerable to introduction and spread of non-native plants along disturbance pathways. Currently, there are 31 known species documented in the region; eighteen of which are considered “highly invasive” (AKEPIC, 2017), including *Vicia cracca* (Bird vetch). *V. cracca* has emerged as a high-ranking management priority, relative to the other species.

A regional-scale control strategy for invasive, non-native plants has been approved for the use integrated control methods to protect fish habitat, wildlife habitat and other resource values in the area (USDI, 2013). The strategy calls for the utilization of a cooperative, interagency approach to monitoring, early detection and rapid response. It also assessed the impacts of the use EPA-approved herbicides with guidance for herbicide safe application and monitoring practices. Stakeholders agencies, groups and individuals were consulted through the NEPA process and there was a determination of no significant impacts resulting from the use of herbicides, if the best practice mitigation measures were followed. It was concluded that the social and ecological benefits of control outweigh any risk of unintended consequences.

Another factor in land management decision-making is the indigenous populations because their land will be impacted by the outcomes of management action or inaction. Drivers of change such as invasive plants are considered a threat to subsistence lifestyles as they are among the top causes in changes in ecosystem services and losses in biodiversity around the globe (MEA, 2005). One Alaska-based study suggests that pollinator disruptions could cause changes in berry habitat that could result in changes to access to foraging (Spellman & Swenson, 2012).

The corridor transects the boreal-arctic transition zone where climate changes are already causing significant shifts in vegetation and wildlife habitat. The ecosystems in this region change relatively quickly with latitude along a steep ecological gradient. The southern portion is largely boreal forest, followed by dry, tundra-covered hills and mountains where the road traverses the Brooks Range. While northern latitudes are vulnerable to climate change, this transition zone is considered particularly sensitive to the impacts. In boreal forests, tree line is shifting northward, wildfires are increasing in frequency and intensity, shrub growth is accelerating, permafrost is thawing, snow conditions are changing, and microbial activity is increasing due to increased soil temperatures (McNew et al., 2013).

Study Concept

The purpose of this study was to first, focus on the interaction between human behavior and human outcomes in the social template; specifically, how much variance in stakeholder management preferences, if any, is explained by individual attitudes toward the outcomes herbicide use. The underlying beliefs, revealed through elicitation and survey of stakeholders, were analyzed according to a social-psychological model of attitude and behavior (Ajzen, 1991). Stakeholders were largely in favor of management action using herbicides to control *V.*

cracca over the course of five years. The analysis rejected the hypothesis that negative attitudes toward herbicides would explain any opposition. It was concluded that the results reflected the level of complexity one might expect from such an unprecedented and uncertain management scenario involving high stakes resources.

Chapter 2 focuses on the implications of the results as they pertain to early detection—rapid response in this case study. Analyses of the beliefs were conducted to inform management about potentially conflicting beliefs that could impede the sustainable implementation of a regional strategy to control invasive species. The target audience for this chapter are stakeholders, land managers and researchers (e.g., wildlife, soils, plants) in context of this case study and in like-cases playing out on public lands of high conservation significance. It was written with the intent to publish in the journal *Biological Conservation.* In conclusion, Chapter 3 addresses the need for greater integration between the results of this social science research and the broader system dynamics by having identified questions to inspire ongoing interdisciplinary research in the context of the PPD framework (Collins et al., 2011).

Cited Literature

AKEPIC (2017). Alaska Exotic Plant Information Clearinghouse database. Retrieved from http://aknhp.uaa.alaska.edu/apps/akepic/). Alaska Center for Conservation Science (ACCS), University of Alaska, Anchorage, AK. (Accessed: December 2017).

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, *50*, 179–211.

Carlson, M. L. & Shepherd, M. (2007, June). Is the Spread of Non-Native Plants in Alaska Accelerating? In T. B. Harrington & S. H. Reichard (Eds.) *Meeting the challenge: invasive plants in Pacific Northwest ecosystems* (pp. 117–133). Gen. Tech. Report No. PNW-GTR-694. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Chapin, F. S., III, Oswood, M. W., Van Cleve, K., Viereck, L., & Verbyla, D. L. (2006). *Alaska's Changing Boreal Forest*. Oxford University Press, New York.

Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., & Gragson, T. L. (2011). An integrated conceptual framework for long-term social-ecological research. *Frontiers in Ecology and the Environment*, *9*(6), 351–357.

Cundill, G., Cumming, G.S., Biggs, D., & Fabricius C. (2012). Soft Systems Thinking and Social Learning for Adaptive Management. *Conservation Biology*, *26*, 13–20.

Eiswerth, M. E., & van Kooten, G. C. (2002). Uncertainty, Economics, and the Spread of an Invasive Plant Species. *American Journal of Agricultural Economics*, *84*(5), 1317–1322.

Evans, M. E., Wilkie, A. C., & Burkhardt, J. (2008). Adaptive Management of Nonnative Species: Moving Beyond the "Either–Or" Through Experimental Pluralism. *Journal of Agricultural Environmental Ethics*, *21*, 521–539.

Fischer, A., & van der Wal, R. (2007). Invasive Plant Suppresses Charismatic Seabird—The construction of attitudes towards biodiversity management options. *Biological Conservation*, *135*, 256–267.

Fischer, A., Selge, S., van der Wal, R., & Larson, B. M. H. (2014). The Public and Professionals Reason Similarly about the Management of Non-Native Invasive Species: A Quantitative Investigation of the Relationship between Beliefs and Attitudes. *PLoSONE*, *9*(8), 1–10.

Gardner, T. A. Ferreira, J., Barlow, J., Lee, C. L., Parry, L., Vieira, I. C., ... Zuanon, J. (2013). A social and ecological assessment of tropical land uses at multiple scales: The Sustainable Amazon Network. *Philosophical Transactions of the Royal Society Series B*, *368*(1619), 1–11.

Lassuy, D. R. & Lewis P. N. (2013) Invasive Species: Human Induced (Chapter 16). In H. Meltofte (Ed.) *Arctic Biodiversity Assessment*, Ayureyri: Conservation of Arctic Flora and Fauna (CAFF).

McNew, L., Handel, C., Pearce, J., DeGange, T., Holland-Barels, L., & Whalen, M. (2013, July). U.S. Geological Survey. *The Role of Ecosystem Changes Across the Boreal-Arctic Transition Zone on Distribution and Abundance of Wildlife Populations*. Anchorage, AK.

Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being: synthesis*. Washington, DC: Island Press.

Miller, J. H., & Schelhas, J. (2008). Adaptive Collaborative Restoration: A key concept for invasive plant management. In R.K. Kohli, J.P. Singh, D.R. Batish & S. Jose (Eds.) *Invasive plants and forest ecosystems*, (pp. 251–265). CRC Press: Boca Raton, FL.

Rejmanek, M., & Pitcairn, M. J. (2002). When is eradication of exotic pest plants a realistic goal? In Veitch, C.R. and Clout, M. N. (Eds.) *Turning the Tide: The eradication of invasive species*, (pp. 249–253). IUCN SSC Invasive Species Specialist Group. Gland, Switzerland and Cambridge, UK.

Schwaller, A. E. (2001). Social dimensions of exotic weed management in national forests and adjacent communities. *Theses, Dissertations, Professional Papers*. Paper 3596.

Selge, S. Fischer, A., & van der Wal, R. (2011). Public and professional views on invasive non-native species: A qualitative social science investigation. *Biological Conservation. 144*, 3089–3097.

Spellman K. V., & Swenson, N. Y. (2012). Assessing the vulnerability of Western Alaska ecosystems and subsistence resources to non-native plant invasion. Western Alaska LCC Cooperative Project.

U.S. Department of the Interior. Bureau of Land Management (2013). Dalton Management Area Integrated Invasive Plant Strategic Plan. Retrieved from https://eplanning.blm.gov/

Chapter 2: Stakeholder Beliefs and Attitudes toward Invasive Plant Management and Herbicides: An Alaska public lands case study[1]

Abstract

Stakeholder support can be key to the success of *early detection—rapid response* efforts to control invasive plants on public lands. To avoid delays due to opposition, a better understanding of the beliefs that comprise these attitudes can help land managers be equipped to navigate differences in management preference. This can better ensure that such strategies are consistent with prevailing stakeholder attitudes, which can be complex and can vary with the social-ecological context. This study explored such a case involving Interior Alaska stakeholder attitudes toward the use of herbicides to control a "highly invasive" plant spreading along the Dalton Highway to assess the beliefs that underlie management preferences. Relevant stakeholders were selected to participate in a web-based survey (n=126) to measure support for a control scenario involving populations of *Vicia cracca* that have become established north of the Arctic Circle. Overall, attitudes toward the potential unintended consequences of herbicide use were no more predictive of management preferences than were attitudes toward the general feasibility and effectiveness of invasive plant management. Also, the beliefs associated with opposition were analyzed and the results showed that the likelihood and the acceptability of eradication, as well as the likelihood of cost effectiveness best explained the differences in management preferences. Survey respondents were asked a series of questions about the "likelihood" and "acceptability" of possible management outcomes over the course of five years. The level of support for the control action as presented in the scenario was high (81% in support) and, generally, participants were aware of the issue (65% of supporters, 67% of opposed). Respondents with prior knowledge of the issue were no more likely to support or oppose the control action. This research is intended to anticipate sources of resistance or acceptances to the existing regional control strategy and improve response efficiency. The intent is to help inform the development of species-specific goals and population-level objectives that are relevant to the affected social-ecological system and sensitive to stakeholder opinions.

Key words: Explicit attitudes; Cognitive beliefs; Invasive plant management; Herbicides; Eradication; Alaska public lands; Early detection-rapid response

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[1] Callear, T. L., Fix, P., Brinkman, T., & Graziano, G., Stakeholder Beliefs and Attitudes toward Invasive Plant Management and Herbicides: An Alaska public lands case study. In preparation for submission to *Biological Conservation*.

Introduction

Invasive plants are known drivers of change in natural areas. For land managers to protect resource values and minimize impact and control costs, early detection-rapid response (EDRR) is favored as an easy and cost-effective strategy to control small, isolated populations (Radosevich, 2002, cited in Spellman & Swenson 2012; FICM-NEW, 2003). However, for this strategy to be sustainable, managers must proactively weigh the potential impact costs of biodiversity loss and ecosystem service impairment, against the often-high costs of prevention, control and restoration (Schworer et al., 2014). This requires finding a balance between overinvestment that fails to reduce impacts and wastes money on unnecessary or ineffective treatment, and underinvestment that wastes money incurring social and ecological impact costs that outweigh the savings (Yokomizo, Poosingham, Thomas & Buckley, 2009).

Timing and support are key to achieving this balance in natural areas because stakeholder opposition can hinder the success of EDRR efforts (Antonio, Jackson, Horvitz & Hedberg, 2004; Carroll, 2014). Delays can be a problem because impact and control costs tend to rise exponentially over time with the size of the infestation (Rejmanek & Pitcairn, 2002; Selge, Fischer & van der Wal, 2011). How best can managers approach an invasive threat proactively, with often uncertain predictions of future distribution and impacts for which there is no historical analog? Such high levels of uncertainty can make it a challenge to communicate with stakeholders who want a straightforward management response and cost-effective outcomes. To cope with uncertainty while minimizing impact costs, Federal public land management agencies are encouraged to pursue a cooperative approach to achieve cost-efficient and effective control of invasive plants that pose a threat to resource values (Executive Order 13751, 2016). Cooperation is recommended in the process of decision-making with regards to control need, timing, and intensity. Such engagement can help integrate different perspectives regarding environmental risks and thereby arriving at more socially acceptable management objectives.

Increasingly, land managers are adopting cooperation with stakeholders as a strategy for overcoming the barriers to successful invasive plant management (Donaldson & Mudd, 2010). For instance, in Interior Alaska, a strategy that calls for a cooperative approach for monitoring, early detection and rapid response was approved for all invasive plants within the Dalton Highway corridor, part of the Central Yukon region (USDI, 2013). The plan recommended using integrated methods, including the use of EPA-approved herbicides, to minimize the impact to fish habitat, wildlife habitat, and other resource values from invasive plants at the regional scale. The plan is not specific to any one species or ecosystem, but rather toward all invasive plant species in the corridor; of which there are currently 31 known species of which 18 are "highly invasive" (AKEPIC, 2017). The corridor encompasses over two million acres of land north of the Yukon River and south of Slope Mountain and is essentially managed as a buffer to nearby areas of high conservation significance (e.g., Kanuti National Wildlife Refuge and Gates of the Arctic National Park).

During the planning process, stakeholder agencies, groups and individuals were consulted and through the NEPA process there was a final determination of "no significant impact". Despite the lack of opposition voiced in the stakeholder consultations, past resistance to the use of herbicides elsewhere in the state suggests that there is potential for resistance in this case. For instance, in 2009 the Alaska Community Action on Toxins (ACAT) and ally organizations through legal challenges successfully ceased the use of herbicides and pesticides on all Alaskan Wildlife Refuges and adjacent lands. Again in 2009, ACAT submitted technical comments to the National Park Service citing the "deleterious effects of herbicides on fish and wildlife", (ACAT, 2018) causing implementation delays followed by more significant NEPA documentation.

To ensure there are no delays in the implementation of future control efforts in the region, research is necessary to better understand any potentially negative attitudes that may arise. A negative attitude toward the use of herbicides as the specific method of control for *V. cracca* was hypothesized as having a stronger influence on management preferences than the overall efficacy and efficiency of invasive plant management, in general. Previous investigations have suggested that unintended consequences, ineffectiveness and inefficiency are critical reasons for stakeholder opposition to invasive plant management using herbicides (Prinbeck, Lach & Chan, 2011). It was expected that those that oppose would express beliefs that herbicides do "more harm than good".

The intent of this research is to answer the following questions to help management anticipate the source of possible resistance to the existing control strategy and overcome beliefs that could become barriers to successful implementation of the Strategic Plan:

1. Among the management preference groups (support or oppose), did attitudes toward herbicides explain a preponderance of difference between the two?
2. To what extent do beliefs about the likelihood and acceptability of negative outcomes explain the difference in management preferences?

Answering these questions can help support the development of a targeted outreach plan on public lands in this region of Alaska, while possibly helping like-cases identify potential barriers to implementing an EDRR strategy to control invasive plants proactively.

Study Background

Research model

The study of beliefs and attitudes toward invasive plant management has received limited research attention. There remains a need for more exploratory studies focused on understanding the determinants of stakeholder support or opposition to invasive plant control action using herbicides on public lands. This research developed and tested a model (Figure 2.1) specific to this purpose using as a foundation the assumptions of the well-established social psychological "theory of planned behavior" (TPB) to assess the cognitive determinants of management preferences (Ajzen, 1991). The TPB has been applied widely in the social sciences related to natural resource management and conservation (e.g., Kaiser, 2006; Miller, 2017; Prinbeck et al., 2011). The value of the TPB is noteworthy, as it has become one of the most frequently cited and influential models for understanding human behavior (Ajzen, 2011).

The TPB states that individual expectations about engaging in a behavior (e.g., support or opposition) are based on behavioral and normative beliefs, which influence their attitude, intention, and ultimately behavior. Beliefs are considered the driving force behind individual attitude and are determined by the perceived consequences of engaging in a behavior. Such beliefs that influence behavior may include both instrumental (e.g., good—bad) and affective (e.g., pleasant—unpleasant) (Connor & Armitage, 1998). Keeping with the tradition of the TPB, this research focused on the instrumental beliefs about the outcomes of invasive plant management action in the specific social-ecological context. Assessing the psychosocial factors that influence individual behavior, such as the subjective norm and perceived behavioral controls was outside the scope of this research.

A critical element of the TPB is the reliance on the specific correspondence between behavior and attitude is strongest when the attitudinal predictors and behavioral criteria are uniquely related to the context of the subject. In other words, the TPB assumes that the utility of the attitude construct is maximized when there is high correspondence among a) the action, b) the target at which the action is directed, c) the context in which the action is performed, and d) the time at which it is performed. The strength of an attitude-behavior relationship depends in a large part on the degree of correspondence between these entities.

High correlation cannot be expected in the absence of attitude behavior correspondence (Ajzen & Fishbein, 1977). As applied to this study, the targets of the attitude are both the species (i.e., *V. cracca)* and use of the herbicide (i.e., *chlopyralid*) as a control method and the action is the decision to implement the control strategy. The social-ecological context is the infested area north of the Arctic Circle along the Dalton Highway in Alaska and the timing for the proposed action is five years. “Support for management action” is the behavior of interest and “intent to support” is used as a proxy for its measurement, as it is the best predictor of future support behavior (Ajzen, 1991). Additionally, intent to engage in a behavior is presumably related to the acceptability and likelihood of the outcomes of the behavior.

Among the beliefs discussed in the literature on attitudes toward invasive plant management, two attitude barriers were identified by a case study that also applied the TPB (Prinbeck et al., 2011). These beliefs were also incorporated into this conceptual research model as two distinct attitude domains: (1) the general “attitude toward invasive plant management” and (2) the specific “attitude toward herbicides”. Although there are other behavioral determinants, this research was strictly interested in explicit attitudes and instrumental beliefs.

Case study

The affected north-south corridor (Figure 2.2), the Dalton Highway, was built in 1974 as an industrial haul road to access the Prudhoe Bay oilfields near the Arctic Ocean. The roadway roughly parallels the Alyeska Pipeline and was restricted from public access until 1994 when it was opened for public access to tourism, recreation and research. It is maintained by the State of Alaska Department of Transportation and crosses the Central Yukon Region (CYR), which is 16 million acres of federal public land under the jurisdiction of the Bureau of Land Management (BLM). The CYR planning area shares boundaries with an array of neighbors including four boroughs, 24 remote villages, 15 tribal entities and three Alaska Native Claims Settlement Act (ANCSA) corporations. Other neighboring federal lands include the Gates of the Arctic National Park and Preserve, Koyukuk National Wildlife Refuge (NWR), Nowitna NWR, Innoko Northern Unit NWR and Kanuti NWR.

The regional-scale control strategy for invasive, non-native plants approved for the use integrated control methods to minimize impacts to fish habitat, wildlife habitat and other resource values in the area (USDI, 2013). It called for the utilization of a cooperative, interagency approach to monitoring, early detection and rapid response and assessed the impacts of the use of EPA-approved herbicides with guidance for herbicide safe application and monitoring practices. Stakeholders agencies, groups and individuals were consulted through the NEPA process and there was a determination of no significant impacts resulting from the use of herbicides, if the best practice mitigation measures were followed. Overall, the conclusion was that the use of integrated methods, including herbicides, would result in the effective control of invasive plant infestations and benefit water resources and ecosystem integrity. Furthermore, it was concluded that any minor, short-term adverse impacts of herbicide use would be outweighed by the moderate, long-term benefits to water resources due to the control of invasive plants. Any potential adverse impacts to wildlife and habitat were addressed and possible non-target impacts would be “no more than minor” as animals may be exposed to small residual amounts of herbicides. Despite the lack of opposition voiced in the stakeholder consultations, it is believed that there are potentially conflicting beliefs that underlie the attitudes toward control action using herbicides when considering specific control actions.

The strategy also ranked the invasiveness risks of known non-native plant species within the corridor and approved a decision tree for setting broad-scale management objectives for each individual species. Through this process, *V. cracca* and other “highly invasive” species have emerged as management priorities in the Koyukuk River drainage. Eradication using herbicides and other methods (i.e., manual and mechanical) was the stated objective for managing *V.cracca.* The five-year life of the seed bank and the limited regional extent of the distribution has positive implications for eradication (USDI, 2013), as research has shown that eradication of invasive plants smaller than one hectare is usually possible and that the cost increases with size (Rejmanek & Pitcairn, 2002).

Native to Europe, *V. cracca* can now be found throughout much of the U.S. and Canada. Records reveal that it was first planted in Alaska at the now closed Rampart Experiment Station on the Yukon River in 1909. Evaluation of its forage potential by the various Alaskan agricultural researchers continued until the early 1970’s. It has since escaped cultivation and is no longer considered a crop or horticultural plant in Alaska (Klebesadel, 1980; Nolen, 2002). Today, much of the *V. cracca* population of Interior Alaska occurs in Fairbanks, however it has continued to spread north along the Dalton Highway. In 2004, *V. cracca* was first documented north of the Yukon River Milepost 55 and has since been observed as far as Milepost 190 (Figure 2.2). The infestation is found mainly along the roadside; however, it has been observed encroaching upon unburned areas within burn perimeters (pers. comm., July 2015). Research has suggested that burned areas could offer an avenue for spread into nearby intact boreal ecosystems (Villano & Mulder, 2008).

Vicia cracca was selected as the target species for this case study due to its invasive tendencies, distribution and rate of spread. Well-suited to the Interior Alaska climate (Carlson et al., 2008*)* *V. cracca* has developed a reputation as the “Alaska Kudzu” (Conn et al., 2007) due to its climbing ability and growth habit of forming dense monocultures. The characteristics that make *V. cracca* an invasive threat include rate of growth, drought tolerance, cold hardiness and adaptability to soil textures (USDS NRCS, 2017). It is also known to alter soil nutrient balance by fixing nitrogen, which is an important factor because the Alaskan Arctic has nutrient poor soils (Wagner, 2017). It can climb over and crowd out shade intolerant plants. For structural support, *V. cracca* tendrils cling to and climb up whatever is in reach, including fences, trees, shrubs, grasses road signs. Roadside fences covered in *V. cracca* can reduce visibility and change snow-drift patterns.

Methods

Sampling method

Issue awareness was critical to the focus on explicit attitudes and therefore it was a priority to engage stakeholders closest to the matter. In the interest of studying relevant stakeholders, the target population included those with stake in the affected Interior Alaska resources. Selection of the final subjects was a census of plausible candidates for collaboration; guided by a comprehensive list recommended by Miller and Schellhas (2008) for collaborative invasive plant management (Table 2.1). Representatives from key stakeholder groups were selected according to a stratified sampling approach that divided the entire population into 1) citizen groups (i.e., environmental and other advocacy), 2) conservation and land management professionals, 3) researchers and scientists and 4) infrastructure and tourism. Surveys were sent to every member of that population (N=913). To assess representation of the completed surveys, the population was collapsed into two stakeholder groups: public comments and inter-agency consultation. The proportion those groups in the population was compared to the proportion within the completed surveys.

Belief elicitation and survey methods

The specific salient instrumental beliefs about the outcomes of support for management action were gathered through a web-based elicitation (Ajzen & Fishbein, 1980). The elicitation technique is commonly used in the social sciences to gather information directly from individuals. Elicitations can be conducted through interviews, observation, focus groups or surveys. Despite the central importance to the TPB, there has been little theoretical discussion about the best way to conduct the elicitation (Sutton et al., 2003), therefore choosing the appropriate method for this investigation was based on the purpose of the study, level of expected cooperation, and the availability of time and resources. The questions used in the elicitation were based on those recommended by Ajzen and Fishbein (1980), in which it is assumed that when deciding whether to engage in a behavior with uncertain outcomes, individuals weigh their perceived beliefs about the advantages and disadvantages of the outcomes (Ajzen, 1991). The use of salient beliefs reduces measurement error because they are considered more representative of actual attitudes. The decision rule for analyzing the elicitation results further recommend the inclusion of 10–12 of the beliefs most frequently mentioned in order to best capture the range of possible beliefs. Two open-ended questions were included in a web-based questionnaire delivered via email to a representative sub-sample (n=12) of the study population. This elicitation took place during April 2016. Eleven of the most frequently mentioned outcomes were drawn from the elicitation results to construct the survey for the larger sample, based on the suggestion of Ajzen and Fishbein (1980). These beliefs were grouped according to the two negative attitude orientations described by Prinbeck et al. (2011), attitude toward invasive plant management (i.e., "losing battle") and attitude toward herbicides (i.e., "more harm than good").

The web-based survey was distributed during June and July of 2016 with no financial incentives to encourage participation (Appendix A). Respondents were asked their level of support for the control of *V. cracca* using herbicides (i.e. chlopyralid) over the course of the next five years. A five-point rating scale was used with options of "Definitely certain to support" (= 2), "Somewhat certain to support" (= 1), "Neither support or oppose" (= 0), "Somewhat certain to oppose" (= -1) and "Definitely certain to oppose" (= -2). Respondents were also asked about their beliefs on an evaluative semantic differential scale of bipolar adjectives (Ajzen & Fishbein, 1977). Traditionally, the recommended scale would ask respondents to evaluate the probability of the outcome (e.g., likely–unlikely) and the quality of the outcome (e.g., good–bad). The "good—bad" spectrum did not accurately capture the complexity of attitudes, therefore an alternative scale better suited for evaluating risk was chosen. Instead, respondents evaluated the likelihood and acceptability of specific outcomes on a seven-point scale of "Highly likely/acceptable" (= 3), "Moderately likely/acceptable" (= 2), "Somewhat likely/acceptable" (= 1), "Neither likely/acceptable or unlikely/unacceptable" (= 0), "Somewhat unlikely/unacceptable" (= -1), "Moderately unlikely/unacceptable" (= -2), or "Highly unlikely/unacceptable" (= -3). Respondents were also asked to report on a three-point scale (yes = 1, no = -1, neither = 0) whether they were aware of this invasive plant issue involving *V. cracca* along the Dalton Highway.

Data analysis methods

The mean of nearby points method for missing values (IBM, 2017) was utilized for respondents that omitted no more than one belief evaluation response. All statistical analyses were carried out using SPSS v. 25.0 (IBM, 2017) at the 5% significance level for all tests ($\alpha = .05$). To explore what type of attitude has a more significant influence, two different attitude domains were considered; attitudes toward both invasive plant management in general, and toward herbicides specifically. Binary logistic regression was used to determine how much variance in management preferences, if any, is explained by these two attitude domains. This statistical test requires that the dependent variable is a binary categorical variable, therefore "intent to support" was collapsed into a new dichotomous variable: "management preference" (support = a score of 1 or 2; oppose = a score of 0, -1 or -2). Those that reported "neither support or oppose" (n=4) were assumed to be *potentially* opposed due to their uncertainty. This statistical method does not assume a linear relationship nor does it require normal distribution or equal variance.

To determine which individual beliefs best explain the differences in attitude and management preference, the central tendency of the distribution of the belief evaluations were explored. The purpose was to ascertain the effects of beliefs about both the "likelihood" and "acceptability" of the outcomes of individual stakeholder's reported intent to support or oppose the control scenario. The mean of the various beliefs that comprise individual attitudes were compared between the two groups, support and oppose, to determine which of the underlying beliefs best explain the variation in management preferences among stakeholders (median was used to correct for non-normal distribution). Those beliefs with a mean/median of a relatively high magnitude (>1.5) were assumed to have a strong influence on management preferences; beliefs with a large difference between the support and oppose groups are assumed to have a strong influence on the direction of the management preference. Also, the difference in attitude between those who aware of this management issue and those who had not, was analyzed using chi-square tests.

Open-ended responses for the support group were coded into six major categories (i.e., environmental protection, highly invasive concerns, early detection-rapid response, multiple methods, and skepticism despite support). The non-support responses were coded into four other categories (i.e., non-issue, general environmental concerns, more harm than good). Responses that mentioned multiple issues, were coded in multiple categories.

Results

Of the surveys sent (N=913), a total of 148 were completed and 22 were eliminated due to missing data (n=126). This provided an error rate of +/-8%, and although this is slightly higher than the desirable error rate of 5%, the data collected were sufficient to detect the differences in the population. To assess representation of responses, the sample was categorized into the following two categories: public stakeholder input versus interagency consultations. The population consisted of 74% public stakeholders and 26% interagency individuals. Although the majority of the targeted population was public, the group made up only 25% of the respondents. It is valuable to note that the public in this case might have been somewhat under-represented. Although the two groups did not differ significantly on management preference (29% vs. 16% opposed, respectively; (X^2 [1,126], p =.103), because of the low statistical power, data were weighted to assess the impact of this potential under representation of the public. A closer look at the management preferences revealed that the weighted percentage of those that support versus oppose did not result in a change of practical significance (81% vs 19% and 74% vs 24%, respectively).

Management preference and stakeholder awareness

Management preferences were largely in favor of management action. Among participants (n=126), there were 102 in support (81%) and 24 in opposition (19%). Whether an individual was aware of the issue prior to the survey did not help to explain the differences in management preferences. Awareness was high among both groups. Among supporters, 65% (n=66) of those surveyed were aware of the issue, while 67% (n=16) of those opposed also reported having been aware of the issue. A chi-square test of independence was performed to examine the relationship between awareness and management preference. The relation between these variables was not significant (X^2 [2,126] =.166, p = .923).

Attitudes toward invasive plant management and the use of herbicides

The data were approximately normal in distribution and the model was statistically significant, indicating that together, these two attitude domains reliably distinguished between those that support and those that oppose (X^2 [1,126] = 40.912, p <.001). The Hosmer and Lemeshow Test for goodness-of-fit (p = .920) indicated that the full model prediction does not significantly differ from the observed, and is therefore is a good fit. Therefore, the addition of each of the two attitude variables to the equation adds to the predictive power of the model, making it possible to draw inferences about the underlying beliefs.

Attitudes directed specifically toward herbicides were expected to be a stronger predictor of management preferences than general attitudes toward invasive plant management. The Wald criterion demonstrated that both attitude domains made significant contribution to prediction (p_{herb}< .001 and p_{ipm}< .001); and the relationship with management preference was approximately the same for the two domains (Exp [B_{herb}]=1.645 and Exp [B_{ipm}]=1.514). Therefore, these results suggest that effect of attitudes toward herbicides did not do more to explain management preferences.

<u>Beliefs about the likelihood and acceptability of negative outcomes</u>

Beliefs elicited about the likelihood and acceptability of potential negative outcomes of invasive plant management using herbicides (Table 2.2) were further examined to determine their influence on overall attitudes. As expected, the overall direction of the components of individual attitudes were positive for those that support and negative for those that oppose; except for eradication beliefs (Figure 2.3). However, closer examination of the underlying beliefs used to calculate individual attitude scores revealed unexpected results. At the outset of the investigation, it was anticipated that stakeholder groups would have similar beliefs about the acceptability of the negative outcomes, but would differ on the likelihood. The results revealed a different picture. Neither those that support nor those that oppose felt that negative outcomes were likely; while differing on willingness to accept negative outcomes (Figure 2.4 & Figure 2.5).

Those beliefs that best explained the difference were the likelihood of eradication, and both the acceptability and likelihood of the long-term cost effectiveness (mean difference = 2, 2.32, and 3.0, respectively). Although the groups have significantly different beliefs about the acceptability of risk of failed eradication, neither have strong negative beliefs. Furthermore, regarding the likelihood of a successful eradication, groups differed significantly and those that support were significantly more optimistic about the likelihood of a successful eradication. Additionally, the support group was less willing to accept the risk of control efforts not being cost effective. Those that oppose were neutral on the likelihood of the outcomes being cost effective, whereas, supporters reported strong, positive beliefs.

As for the beliefs specific to the use of herbicides, the management preference groups expressed significantly different levels of willingness to accept the risk of impacts to human health. Those that oppose did not report feeling as strongly as supporters did about the unacceptability of risk to human health. Both groups feel strongly that negative impacts to human health are unlikely. The groups also expressed significantly different levels of willingness to accept the risk of impacts to wildlife health and water quality alike. Those that oppose were more willing to accept the risk of impacts to wildlife health and to water quality than were supporters. The groups also expressed significantly different levels of willingness to accept the risk that chemicals may persist in the environment. Those that oppose are significantly more accepting of the risk of chemical persistence. The groups differed significantly on their beliefs about the likelihood for persistence of herbicidal chemicals. Those that oppose feel rather strongly that chemical persistence in the environment is unlikely. Those that oppose feel more strongly that negative impacts to native plants are unlikely. Those opposed feel somewhat strongly about the acceptability of the risk of impacts to native and supporters on average agree, but are much more neutral. In order to understand what may have been driving management preferences, the open-ended comments were analyzed to help interpret the results.

Open-ended comments

Forty-seven respondents (36 supporters, 11 non-supporters) provided a written explanation to the open-ended question that asked the respondent for comments in response to the issue. Among supporters, 22% promoted the use of herbicides for environmental protection, 42% commented on the highly invasive nature of the species, 33% emphasized the need for an efficient early response, 39% urged the use of integrated methods (e.g., prevention, restoration, mechanical), 31% promoted the safe use of herbicides, and 17% voiced skepticism about the need for management action. Among those opposed, the results showed 45% of respondents commenting (n=6/11) believed that invasive plants are not a valid management issue and that, environmentally there are “bigger fish to fry,” 27% (n=3/11) felt that management action was a “losing battle” and either too expensive or not possible, and 27% (n=3/11) stated reasons for believing that such action would cause “more harm than good”.

Discussion and Conclusions

This study attempted to provide a wider view of public opinion on the control of one highly invasive species, *V. cracca,* in the Dalton case. The following discusses the demonstrated role of stakeholder beliefs about the outcomes of control of *V. cracca* using herbicides. Better understanding stakeholder management preferences can improve the chances of success and can help inform educational messages to address any barriers to achieving sustainable outcomes (Prinbeck et al., 2011).

Attitudes toward invasive plant management and the use of herbicides

There has been some research about attitudes and beliefs held by stakeholders regarding invasive plants, but very few have applied the TPB. In a study of the relationship between beliefs and attitudes among the public and professionals in Scotland, Fischer, Selge, van der Wal and Larson (2014) applied a quantitative model that revealed that perceptions informed attitudes in very similar ways across the two groups. They also found that support for management was often a function of beliefs about abundance, controllability, perceived beauty, impact on the economy and on nature. Another study in Scotland by Bremner and Park (2007) assessed public attitudes to the management of invasive non-native species.

The study found that respondents with prior knowledge of control and eradication programs and members of conservation organizations showed higher levels of support. Many survey participants commented negatively about the use of herbicides and pesticides, but there was a discrepancy between their desire to control and their distaste for the methods necessary to control them. Both studies suggest that a participatory approach to stakeholder involvement is important for increasing support for control efforts, increasing success rates and reducing risk of delays. This research found a strong relationship between stakeholder attitudes and management preferences in the Dalton case. However, like the Bremner and Park study, beliefs were not entirely consistent with their management preferences. The following discusses the determinants of the underlying beliefs and levels of awareness to better understand the individual decision to support or oppose management action.

Beliefs about herbicides

Herbicides, in general, are poisonous chemicals that are used to kill unwanted plants and can therefore be inherently contentious. According to the EPA, it is possible to use many herbicides without risk of serious harm to humans and the surrounding biotic and abiotic environment. Despite the evidence cited by the BLM that the selected herbicide in this Dalton case management scenario (i.e., *chlopyralid*) can be used safely (USDI, 2007) the unprecedented nature of its use in boreal-arctic ecosystems lead to the hypothesis that differences in attitudes toward herbicides could have a strong influence on management preferences. The opposed group were expected to have strong beliefs that negative outcomes were likely; with a strong unwillingness to accept the negative outcome potential. The expectations were incorrect and the opposition group seemed to be largely motivated by skepticism toward the prioritization of invasive plant management. This could be because they are well informed about the consequences but do not see them as unacceptable, or because they are poorly informed about the potential for such consequences.

Although management preferences were largely in support, and attitudes toward herbicides did not explain a significant difference in the management preference groups, some of those opposed did provide revealing comments reflecting the sentiment that the control method could be more harmful to the environment than invasive species themselves. This idea that control activities such as herbicides may be counterproductive and possibly a source of harm in their own right is reflective of debates found in the literature on invasive plant management (Evans et al., 2008; Prinbeck et al., 2011; Sagoff, 2005). Although overall the data did not support this, 27% of those opposed that provided open-ended comments cited reasons for believing that herbicides would cause “more harm than good”, with one stating specifically that “there is no reason to use herbicides” and that the “supposed cure is worse than the problem.”

Although a few stakeholders echoed these beliefs, most stakeholders believed that the threat of unintended consequences or non-target effects (human, wildlife, water) was minimal. In fact, those opposed reported being more willing to accept five out of the eleven negative outcomes related to herbicide use than were the supporters (Figure 2.5). Both management preference groups felt strongly that the potential effects to wildlife health or water quality are unlikely. Those that oppose did express strong positive beliefs about their willingness to accept the risk of impacts to wildlife health, whereas supporters are comparatively much less accepting of the potential risk. This is aligned with the findings of the environmental assessment for the control strategy in the Dalton case, which stated that the potential adverse impacts to wildlife and habitat along with other possible non-target impacts would be no more than minor as animals may be exposed to small residual amounts of herbicides. Overall, it was concluded that it should be beneficial to wildlife and habitat by preventing the long-term establishment of invasive plant species (USDI, 2013).

<u>Beliefs about invasive plant management</u>

Given the high costs of control and the complexity and uncertainty that shroud the decision to eradicate an invasive plant species, it comes as no surprise that the study of the invasive phenomenon has attracted a significant amount of criticism from natural and social scientists, policy-makers, managers, and stakeholders. While many conservationists are strongly in favor of aggressive efforts to control and eradicate invasive plants, still others are hardened skeptics that call into question the fundamental assumptions of the invasive phenomenon (Evans et al., 2008). Based on the comments from open-ended comments, this dichotomy did nearly as much to explain the differences in management preferences as did the choice of herbicides as a method, as originally anticipated (17% and 22% of opposed open-ended comments, respectively). Beliefs about eradication and cost-effectiveness were significant determinants of overall attitude toward invasive plant management.

Among the explanations for differences in management preferences related to beliefs about invasive plant management reported in the literature are opinions about eradication feasibility and cost-effectiveness (e.g. Evans et al., 2008; Simberloff, 2002). Although a strong case for eradication can be made based on scientific evidence of the benefits of conserving biodiversity (Craik, 1998, cited in Bremner & Park, 2007), a case can be made in opposition. This debate can cause problems for rapid response since conflicting stakeholder and management goals can frustrate eradication attempts (Bomford & O'Brien, 1995) and reduce the chances of success.

In this Dalton case study, supporters reported high expectations for cost-effective eradication and a low tolerance for failure. They qualified their statement with open-ended comments emphasizing the need for cost-effective eradication. While supporters were significantly more optimistic about the chances of success, those that opposed tended toward neutral on the issues and did not express strong feelings either way.

For some, eradication may be appealing as an objective, possibly due to the potential to remove the threat of impacts and the recurrent costs of control. However, despite the appeal, there are few plant eradication success stories documented in the literature. Eradication success stories are predominantly showcasing mammal and insect eradications. Among the few success stories in Alaska is the control effort targeting the red fox (*Vulpes vulpes*), that eradicated the species from 39 islands in the Alaska Maritime National Refuge (Ebbert & Byrd, 2002). More recent milestones that reported having eliminated *Elodea spp.* from the busiest seaplane base in the world (i.e., Lake Hood in Anchorage, Alaska) offers hope for eradication success in the larger statewide effort to eradicate highly invasive plant species in Alaska (Stewart, 2015).

As important as such success stories may be in garnering support for future efforts, some high-profile failures (e.g., Genovesi & Bertolino, 2001, cited in Simberloff, 2002) are believed to be the basis for some of the opposition. Particularly where plants are concerned, as eradication efforts targeting plants are often considered a greater challenge than mammals or insects due to the need for securing broad cooperation for long campaigns and sustained removal at high costs. For instance, on a statewide scale, *V. cracca* has been labeled “labor and capitally intensive” in Alaska (Nolen, 2002). Therefore, it is possible that stakeholders that oppose management action may believe that the fight to eradicate invasive species is a losing battle (Prinbeck et al., 2011).

In general, eradication efforts should be based on accurate benefit-cost analyses and data needed for these calculations are often unavailable. Even if eradication is more cost effective than no control, the benefits of eradication must be weighed against alternatives. The benefits of retaining the target species also need to be considered. For example, in the Dalton case, one participant in the elicitation pointed out the potential benefits of *V. cracca* for bank stabilization and ground cover insulation.

It is also possible non-supporters tend towards neutral because they disagree on the degree of invasiveness of the species, *V. cracca*. Based on estimations of ecosystem alteration, community alteration, biological characteristics and ease of control, *V. cracca* ranks highly in terms of “invasiveness” (Carlson et al., 2008). So why might some stakeholders still disagree with an early response? Rather than differing on the outcomes of the control action, it is possible that they differ on the invasiveness of the species and the subsequent need for an aggressive early response using herbicides.

The success of some introduced species and failure of others is difficult to predict, and is specific to ecological and climatic conditions (Williamson & Fitter, 1996, cited in Carlson et al., 2008; D’Antonio, 1993; Mack 1996). Many non-native plants do not cause damage in natural ecosystems (Williamson et al., 1996, cited in Carlson et al., 2008). *V. cracca* is one example that is observed primarily in association with anthropogenically disturbed sites and have few known or anticipated negative impacts. From a management perspective, the most problematic invasive plant species are those with poorly understood and intermediate impacts. It is difficult to anticipate their effects on Alaskan ecosystems, which can cause confusion among professionals and the public as to which species ought to be controlled. Additionally, some species that are not problematic in other states, such as *V. cracca*, can prove to be a serious invasive threat in Alaska or similar ecosystems (Carlson et al., 2008).

Invasiveness is a ranking measure used by invasive plant managers to prioritize control actions. A wide variety of invasiveness assessment models have been produced in the last decade. Early frameworks for ranking invasiveness assess the ecological effect based on three fundamental dimensions: range, abundance, and the per-capita or per-biomass effect of the invader, i.e., the magnitude of ecological change it causes (Parker et al., 1999, cited in

Kumschik, 2012). Generally, assessment models evaluate and score spatial characteristics, known or potential impacts on resources of value (e.g., biodiversity, agriculture, water resources, or aesthetics), biological characteristics, and ease of control. The value of the individual ranking systems is clearly related to the aims and context of researchers, and it is unreasonable to expect a single system to be effective in all contexts. Due to the unique social and ecological contexts in Alaska, a specialized system was created. It is a transparent, repeatable, and robust ranking system to evaluate both the likelihood of establishment and the consequences to the ecology and community (Carlson et al., 2008). However, this approach stops short of incorporating stakeholders. In fact, few scoring approaches explicitly address the potentially competing interests of stakeholders (i.e., various ecological, economic or social interests). Stakeholder input in this process is critical because biological invasions represent a complex societal issue highly uncertain management outcomes and prominent conflicts of interests and values (Kueffer & Hadorn, 2008, cited in Kumschik, 2012).

Cited Literature

Alaska Community Action on Toxins (ACAT) Accomplishments (n.d.). Retrieved from https://www.akaction.org/our_story/accomplishments/ (Accessed: 2018, February)

AKEPIC (2017). Alaska Exotic Plant Information Clearinghouse database. Retrieved from http://aknhp.uaa.alaska.edu/apps/akepic/). Alaska Center for Conservation Science (ACCS), University of Alaska, Anchorage, AK. (Accessed: December 2017).

Ajzen, I., & Fishbein, M. (1977). Attitude-Behavior Relations: A theoretical analysis and review of empirical research. *Psychological Bulletin*, *84*(5), 888–918.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs, NJ: Prentice-Hall.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes*, *50*, 179–211.

Ajzen, I. (2011). The Theory of Planned Behavior: Reactions and reflections. *Health Psychology*, *26*(9), 1113–1127.

Antonio, C. M., Jackson, N. E., Horvitz, C. C., & Hedberg, H. (2004). Invasive plants in wildland ecosystems: merging the new study of invasion processes with management needs. *Frontiers in Ecology and Environment*, *2*(10), 513–521.

Bomford, M. & O'Brien, P. (1995). Eradication or Control for Vertebrate Pests? *Wildlife Society Bulletin*, *32*(2), 249–255.

Bremner, A., & Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation, 139*, 306–314.

Carlson, M. L., Lapina, I. V., Shephard, M., Conn, J. S., Densmore, R., Spencer, P., Heys, J., Riley, J., & Nielsen, J. (2008). *Invasiveness Ranking System for Non-Native Plants of Alaska*. R10-TP-143, (pp. 1–24). U.S. Department of Agriculture, Forest Service Alaska Region.

Carroll, S. P. (2011). Conciliation biology: the eco-evolutionary management of permanently invaded biotic systems. *Evolutionary Applications*, *4*, 184–199.

Conn, J., Baer, Z., Werdin-Pfisterer, N., & Mohrmann, K. (2007, November). *Susceptibility of Alaska Plant Communities to Invasion by Bird Vetch*. Presentation at the 8th Annual CNIPM Invasive Species Workshop, Anchorage, AK.

Connor, M., & Armitage, C. J. (1998). Extending the Theory of Planned Behavior: A Review and Avenues for Further Research. *Journal of Applied Psychology*, *28*(15), 1429–1464.

Donaldson, S., & Mudd, T. (2010). Weeds Across Boarders, Sustaining Cooperative Weed Management Areas in the long term. In E. Rindos, (Ed.), *Plant Invasions: Policies, Politics and Practices, Proceedings of the 2010 Weeds Across Borders Conference,* (pp. 88–94). National Conservation Training Center, Shepherdstown, West Virginia.

Ebbert, S. E., & Byrd, G. V. (2002). Eradications of invasive species to restore natural biological diversity on Alaska Maritime National Wildlife Refuge. In Veitch, C.R. & Clout, M. N. (Eds.), *Turning the Tide: The eradication of invasive species. IUCN SSC Invasive Species Specialist Group,* (pp. 102–109). IUCN, Gland, Switzerland and Cambridge, UK.

Evans, M. E., Wilkie, A. C., & Burkhardt, J. (2008). Adaptive Management of Nonnative Species: Moving Beyond the "Either–Or" Through Experimental Pluralism. *Journal of Agricultural Environmental Ethics*, *21*, 521–539.

Exec. Order No. 13751, 3 C.F.R. Page 630–637 (2016). Safeguarding the Nation from the Impacts of Invasive Species.

Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICM-NEW). (2003, September). A National Early Detection and Rapid Response System for Invasive Plants in the United States. Washington, D.C. Retrieved from https://www.fws.gov/ficmnew/ficmnew_edrr_final.pdf

Fischer, A., Selge, S., van der Wal, R., & Larson, B. M. H. (2014). The Public and Professionals Reason Similarly about the Management of Non-Native Invasive Species: A Quantitative Investigation of the Relationship between Beliefs and Attitudes. *PLoSONE*, *9*(8), 1–10.

Kaiser, F. (2006). A moral extension of the theory of planned behavior: Norms and anticipated feelings of regret in conservationism. *Personality and Individual Differences*. *40*, 71–81.

Klebesadel, L. J. (1980). Bird vetch: forage crop, ground cover, ornamental, or weed? *Agroborealis*, *12*, 46–49.

Kumschick, S., Bacher, S., Dawson, W., Heikkila, J., Sendek, A., Pluess, T., Robinson, T. B., & Kuhn, I. (2012). A conceptual framework for prioritization of invasive alien species for management according to their impact. *NeoBiota, 15*, 69–100.

IBM Corp. (2017). SPSS for Windows, Version 25.0. Armonk, NY: IBM Corp.

Miller, Z.D., (2017). The enduring use of the theory of planned behavior. *Human Dimensions of Wildlife*, *22*(6), 583–590.

Nolen, A., Alaska Plant Materials Center, Division of Agriculture, Department of Natural Resources (2002). *Vetch Infestations in Alaska* (Report No. FHWA-AK-RD-02–11). Juneau, AK: Alaska Department of Transportation, Statewide Research Office.

Prinbeck, G., Lach, D, & Chan, S. (2011). Exploring Stakeholders' Attitudes and Beliefs Regarding Behaviors that Prevent the Spread of Invasive Species*. Environmental Education Research*, *17*, 341–352.

Rejmanek, M., & Pitcairn, M. J. (2002). When is eradication of exotic pest plants a realistic goal? In Veitch, C.R. & Clout, M. N. (Eds.) *Turning the Tide: The eradication of invasive species,* (pp. 249–253). IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Sagoff, M. (2005). Do Non-native Species Threaten the Natural Environment? *Journal of Agricultural and Environmental Ethics*, *18*, 215–236.

Schworer, T., Federer, R. N., & Ferren, H. J. (2014). Invasive Species Management Programs in Alaska: A survey of statewide expenditures, 2007–2011. *Arctic, 67*(1), 20–27.

Selge, S. Fischer, A., & van der Wal, R. (2011). Public and professional views on invasive non-native species: A qualitative social science investigation. *Biological Conservation, 144*, 3089–3097.

Simberloff, D., M. J. (2002). Are we aiming too low in invasives control? In Veitch, C.R. & Clout, M. N. (Eds.) *Turning the Tide: The eradication of invasive species,* (pp. 4–12). IUCN SSC Invasive Species Specialist Group. IUCN: Gland, Switzerland and Cambridge, UK.

Spellman K. V., & Swenson, N. Y. (2012). Assessing the vulnerability of Western Alaska ecosystems and subsistence resources to non-native plant invasion. Western Alaska LCC Cooperative Project.

Stewart, H. (2015, October). Elodea in Lake Hood: The stars align in an emergency. *Presentation at the 15th Annual CNIPM Invasive Species Workshop*, Anchorage, AK.

Sutton, S., French, D. P., Hennings, S. J., Mitchell, J., Wareham, N. J., Griffin, S., Hardeman, W., Kinmonth, A. L. (2003). Eliciting Salient Beliefs in Research on the Theory of Planned Behaviour: The Effect of Question Wording. *Current Psychology: Developmental, Learning, Personality, Social, 22*(3), 234–251.

U. S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). (n.d.). Plants Database, Plants Profile for *Vicia cracca* (bird vetch). Retrieved from https://plants.usda.gov/ (Accessed: 2018, February).

U.S. Department of the Interior. Bureau of Land Management (2007). Programmatic environmental impact statement: vegetation treatments using herbicides on Bureau of Land Management lands in 17 western States. Washington, D.C. Retrieved from http://www.blm.gov/wo/st/en/prog/more/veg_eis.html

U.S. Department of the Interior. Bureau of Land Management (2013). Dalton Management Area Integrated Invasive Plant Strategic Plan. Retrieved from https://eplanning.blm.gov/

Villano, K.L., & Mulder, C.P.H. (2008). Invasive plant spread in burned lands of interior Alaska. Final report for National Park Service, Alaska Region and National Aeronautics and Space Administration. Fairbanks, AK.

Wagner, D. (2017, November). The Role of Nitrogen Fixation and Climbing in Competitive Interactions Between Bird Vetch and Native Plants*. Presentation at the 18th Annual CNIPM Invasive Species Workshop*, Anchorage, AK.

Yokomizo, H., Possingham, H. P., Thomas, M. B., & Buckley, Y. M. (2009). Managing the Impact of Invasive Species: The value of knowing the density–impact curve. *Ecological Applications*, *18*(2), 376–386.

Figures

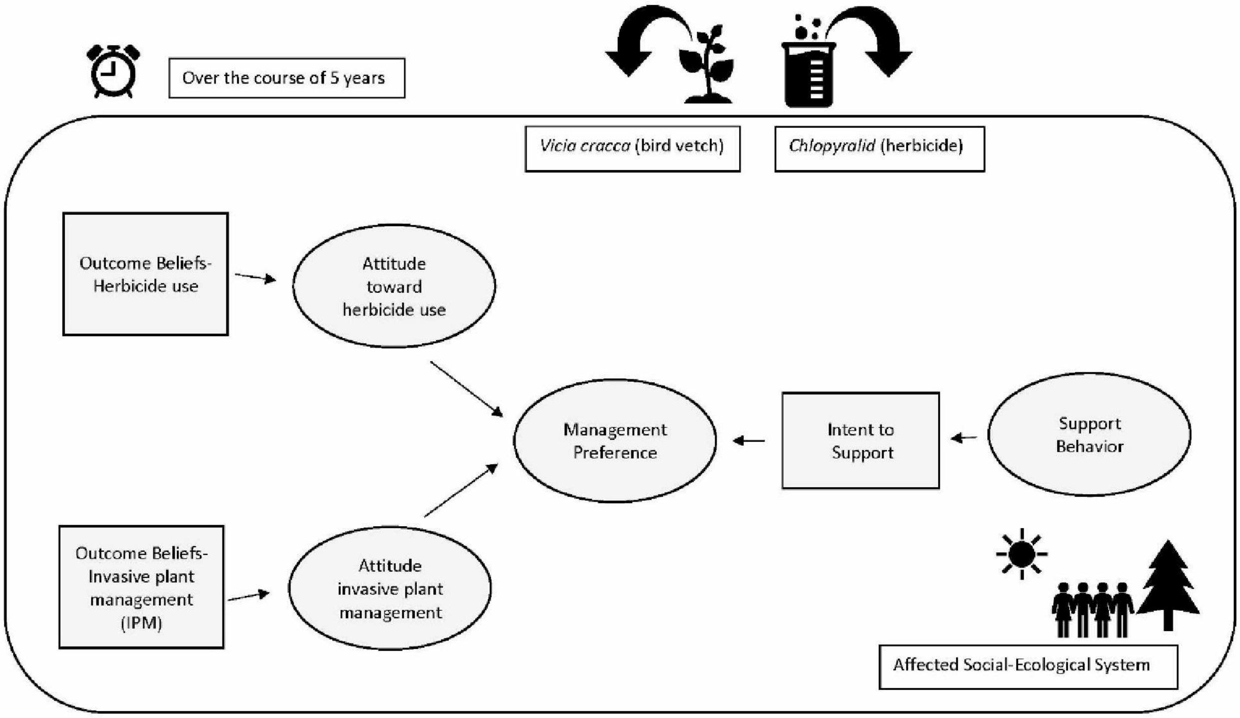


Figure 2.1 Conceptual model of the measured variables (squares) and the related constructs (ovals) in the context of the social-ecological system threatened by the invasion of V. cracca.

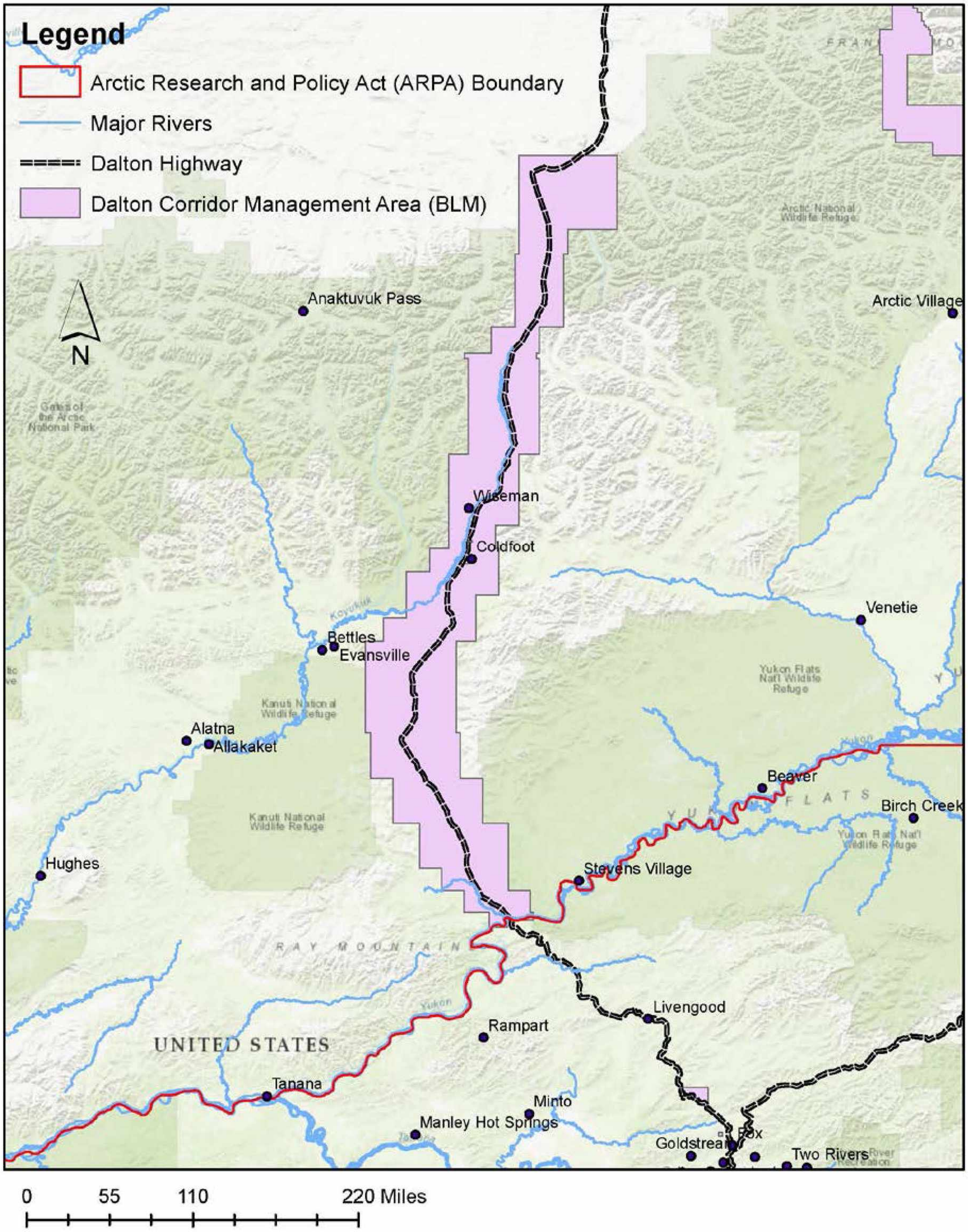


Figure 2.2 Map illustrating the affected Dalton Highway corridor (purple) and nearby conservation areas Kanuti NWR, Yukon Flats NWR, Arctic NWR and Gates of the Arctic NP (green).

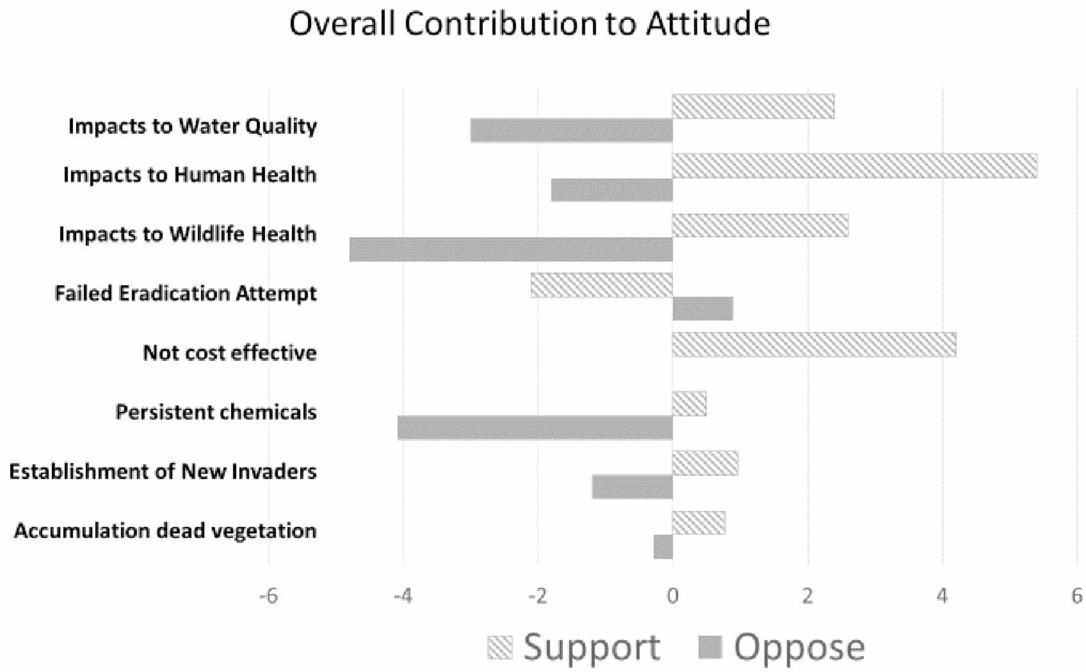


Figure 2.3 Overall contribution of the beliefs to attitude score (i.e., multiplicative combination of likelihood and acceptability beliefs) among management preference groups (support n=102, oppose n=24). Respondents evaluated the likelihood and acceptability of specific outcomes on a seven-point scale of "Highly likely/acceptable" (=3), "Moderately likely/acceptable" (=2), "Somewhat likely/acceptable" (=1), "Neither likely/acceptable or unlikely/unacceptable" (=0), "Somewhat unlikely/unacceptable" (=-1), "Moderately unlikely/unacceptable" (=-2), or "Highly unlikely/unacceptable" (=-3). Shown are those beliefs that were significant in explaining the difference in management preference.

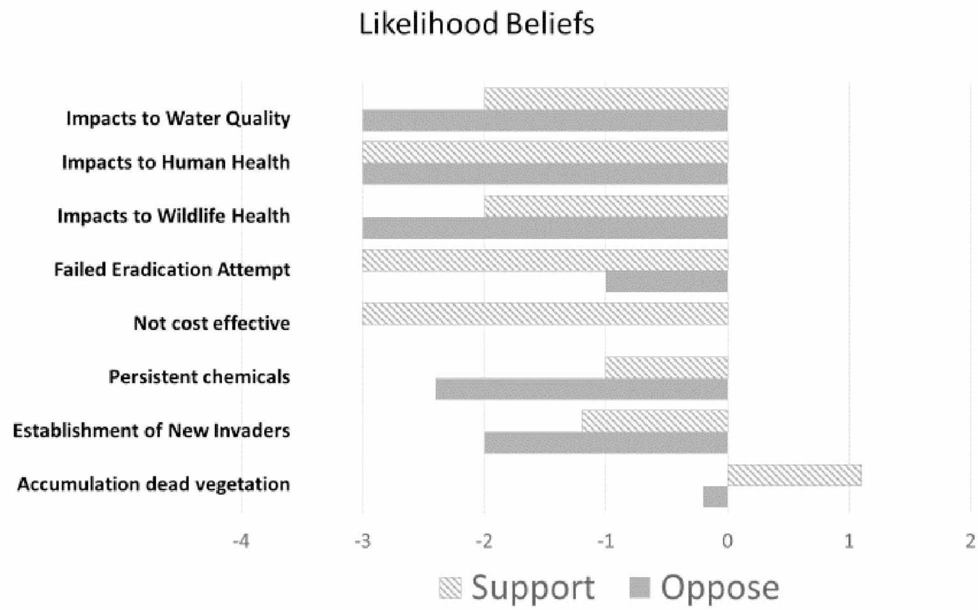


Figure 2.4 Analysis of the central tendency of likelihood beliefs among management preference groups (support n=102, oppose n=24). Respondents evaluated the 'likelihood' of specific outcomes on a seven-point scale of "Highly likely" (=3), "Moderately likely" (=2), "Somewhat likely" (=1), "Neither likely or unlikely" (=0), "Somewhat unlikely" (=-1), "Moderately unlikely" (=-2), or "Highly unlikely" (=-3). Shown are those beliefs that were significant in explaining the difference in management preference.

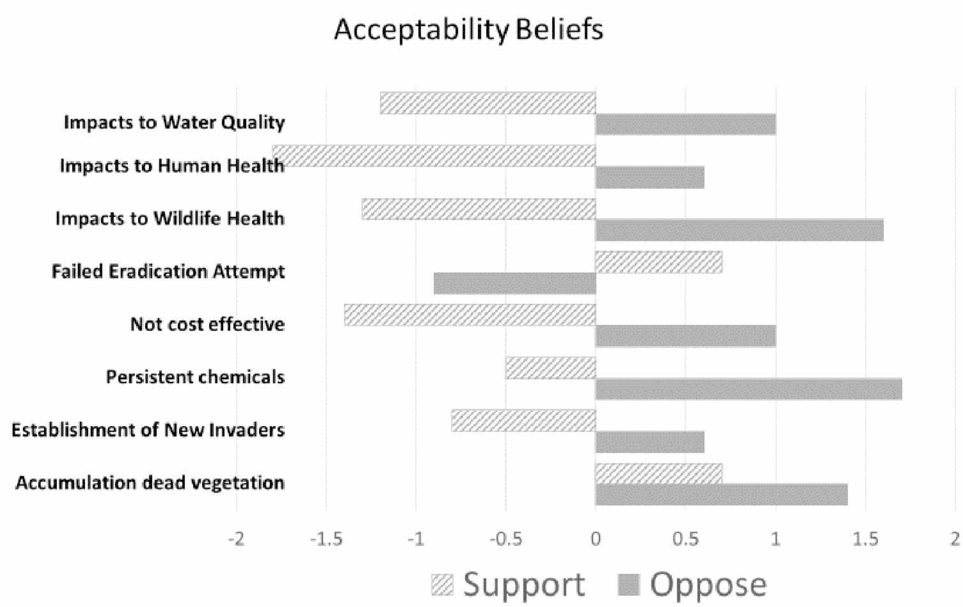


Figure 2.5 Analysis of the central tendency of acceptability beliefs among management preferences (support n=102, oppose n=24). Respondents evaluated the acceptability of specific outcomes on a seven-point scale of "Highly acceptable" (=3), "Moderately acceptable" (=2), "Somewhat acceptable" (=1), "Neither acceptable or unacceptable" (=0), "Somewhat unacceptable" (=-1), "Moderately unacceptable" (=-2), or "Highly unacceptable" (=-3). Shown are those beliefs that were significant in explaining the difference in management preference.

Tables

Table 2.1 The study population was identified as public (#) and agency (*) representatives that are plausible candidates for participation in collaborative planning and control. The population parameters were set according to the comprehensive list recommended by Miller and Schellhas (2008) for collaborative invasive plant management.

Energy development and mining*	Federal resource land management agencies*
State department of natural resources*	Indigenous plant societies#
Fiber optic cable transmission authorities*	Botanical gardens#
State department of transportation/public facilities*	Invasive plant groups and control consultants#
State department of environmental conservation*	University and cooperative extension services*
Anti-toxin advocacy groups#	Village and tribal councils*
Conservation and environmental organizations#	Community planning boards*
Tourism and hunting guides#	County and city-level governing commissions*

Table 2.2 Eleven beliefs about potential negative impacts of invasive plant management using herbicides elicited from a representative sub-sample of the study population.

<u>Beliefs related to herbicides</u>

1. Impacts to human health due to contamination of subsistence resources
2. Impacts to wildlife health
3. Contamination water resources due to leaching
4. Persistence of herbicidal formulations in the Arctic environment
5. Harm to nearby native plants

<u>Beliefs related to invasive plant management</u>

6. Failed eradication of bird vetch north of the Arctic Circle
7. Loss of insulative cover for permafrost where native vegetation has been eliminated
8. Failure to achieve cost effective outcomes
9. Cost of treatment will outweigh the benefits eradication
10. Introduction of new invasive plants after treatment
11. Accumulation of dead vegetation after treatment

Chapter 3: Conclusion

Invasive plants are a known driver of global change encroaching upon boreal-arctic ecosystems. Yet, despite being recognized globally as a threat to biodiversity, the outcomes of each local invasion and management action is highly dependent on the affected social-ecological context. This variability reduces the potential for generalizing research findings across cases. Many studies have looked at the influence of beliefs and attitudes about the outcomes of invasive plant management (Fraser, 2006, cited in Bremner & Park, 2007; Johnston & Marks, 1997). This case study differs in that it aims to establish a repeatable model that is generalizable to like cases. Comparisons across site-based scientific investigations provide important insights into diverse complex characteristics that cannot be observed in a single study. The types of surprises across cases may differ, but they all originated from the interactions between humans and natural systems. When complexity is not understood, people may be surprised by the outcomes which can lead to near-term impacts on management success and long-term ecological or economic effects (Collins et al., 2011; Liu et al., 2007).

Building upon relevant theory and concepts is important to increasing the generalizability of a scientific approach to understanding emerging management issues (Vaske & Manfredo, 2012). Case studies are defined as a detailed examination of a single example of a class of phenomena that capable of providing limited reliable information about the broader class. Although there are limits to generalizing on the basis of an individual case, the study can still contribute to the scientific development of practical, context-dependent knowledge. One way that the generalizability of case study research can be increased by the strategic selection of cases (Ragin, 1992, cited in Flyvbjerg, 2002; Rosch, 1978, cited in Flyvbjerg, 2002). However, typical or average cases do not always produce the richest information; rather, atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation of interest. In this research, this invasive plant management situation threatens high stakes resources and is unfolding in an area undergoing rapid, directional social-ecological change. Such an extreme case was identified as being well-suited for either clearly confirming or irrefutably falsifying the hypothesis that negative beliefs about herbicides were the primary determinant of oppositional behavior directed at management.

The following sections discuss the fundamental relationships conceptualized and analyzed using the PPD model (Figure 1.1). The questions that arise at the interfaces (Q1—Q6) refer to the hypotheses-driven research questions that were derived from the findings from this case study, which can ultimately be used to steer the long-term research agenda. The interactions stemming from the social template (Q1, Q2 and Q6) are the focus of this research; more specifically, these feedbacks are defined as the changes in human outcomes, such as quality of life or perceptions that effect human behavior (Q1), the predictable and unpredictable human behavioral responses that influence the disturbance regimes (Q2) and the changes in vital ecosystem services that alter human outcomes (Q6).

What beliefs about the outcomes of herbicide control of *V. cracca* have a significant effect on management preferences? (Q1)

Based on highly uncertain outcomes of action or inaction, stakeholders are faced with a decision to support or oppose the use herbicides to control *V. cracca*. Their beliefs about the likelihood of the outcomes, as well as their willingness to accept the risk of negative outcomes, are assumed to have shaped their attitudes towards the control action and formed the basis of their decision to support or oppose it. Due to the unprecedented nature of herbicide use in boreal-arctic ecosystems, it was hypothesized that the opposed group would have strong beliefs that negative outcomes were likely; with a strong unwillingness to accept the negative outcome potential. In other words, the use of herbicides was expected to be a source of contention between individuals with opposite management preferences because there is a chance some stakeholders may be more risk averse when it comes to pollution prevention and may object to release of “unnecessary chemicals” into the environment.

Ultimately, the results did not align with the expectation that non-supporters would feel strongly that impacts from herbicides were both unacceptable and likely. Neither group thought that unintended consequences or non-target effects (human, wildlife, water) were likely, and those opposed were actually more willing to accept the potential negative outcomes of herbicide use than were the supporters. If stakeholders that oppose control action do not have negative beliefs about herbicides, then what motivated them to oppose the control scenario? Do they question the sustainability of the effort? Do they disagree with the forecasted impact to the ecosystem services or the value placed on them? Or do they doubt that *V. cracca* poses a real threat to community structure and ecological function? The following discusses the questions raised by in the comparison of the underlying beliefs in the context of the interactions of the PPD framework.

Are sustainable human behaviors and outcomes achievable based on the strategy to control *V. cracca* using herbicides? (Q2)

Applying the concept of sustainability to invasive plant management is important due to the increasing rates of invasion and the high costs of impacts and control. To be sustainable, invasive plant management must address the environmental, social and economic factors that influence the causes, impacts and control across multiple spatial and temporal scales (Larson et al., 2011). Sustainable strategies must integrate multiple methods of cooperative prevention, control and restoration to achieve effective and efficient eradication. Among supporters, 39% of the open-ended responses (n=14/36) emphasized the importance of relying on integrated methods; and 33% (n=12/36) emphasized the need for an efficient early response. On the other hand, 27% of the open-ended responses (n=3/11) given by non-supporters expressed concern that eradication was either too expensive or that control was not possible; and 27% cited reasons for believing that such action would cause "more harm than good."

The stated objective for managing *V. cracca* is eradication using herbicides and other manual and/or mechanical approaches. The five-year life of the seed bank and the limited regional extent of the distribution, is believed to have positive implications for eradication (USDI, 2013); however, the feasibility of achieving eradication that is cost effective is impossible to predict. The results of the survey revealed that, on average, supporters had high expectations for cost-effectiveness and eradication. They also expressed a low tolerance for failure to achieve either objective. And while supporters were significantly more optimistic about the chances of success, those that oppose did not have strong feelings either way. It is possible that they tend towards neutral because neither the species nor the herbicide-use are seen as substantial management concerns.

To date there is no comprehensive strategy for prevention, monitoring or restoration to ensure the successful eradication of *V. cracca.* These elements of invasive plant management will be critical to finding a sustainable balance between overinvestment that fails to reduce impacts and wastes money on unnecessary or ineffective treatment, and underinvestment that wastes money by incurring social and ecological impact costs that outweigh the savings (Yokomizo et al., 2009).

<u>What changes to ecosystem services caused by *V. cracca* are perceived by stakeholders (Q6)?</u>

The concept of ecosystem services is a useful way of assessing the value of changes to ecosystems and natural capital, including those services with no obvious material benefit (e.g., wilderness characteristics, pollination). It was beyond the scope of this study to measure individual attitudes toward the likelihood and the acceptability of the impacts of *V. cracca* on the flow of ecosystem services. Of interest in the boreal-arctic region are the cultural services that a functioning ecosystem provides. Functioning ecosystems in the case study provide cultural services that sustain subsistence lifestyles and the recreation and tourism industries.

Of the open-ended comments by supporters (n=12/36), 33% emphasized the need for an urgent, aggressive approach to protect rivers and biodiversity; while 45% opposed stakeholders (n=5/11) questioned the validity of invasion ecology and the institutions that promote it.

The significance of these findings for the development of a management strategy is stakeholder involvement in the process of assessing the perceived vulnerability of resource values in the affected area and threatened adjacent areas (Spellman & Swenson, 2012). Key to this level of involvement is ensuring that participants understand the issue well enough to inform their position. This research can help managers prioritize information needs for an effective outreach campaign aimed at reducing the risk of impacts to threatened ecosystem service values.

Cited Literature

Bremner, A., & Park, K. (2007). Public attitudes to the management of invasive non-native species in Scotland. *Biological Conservation, 139*, 306–314.

Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., & Gragson, T. L. (2011). An integrated conceptual framework for long-term social-ecological research. *Frontiers in Ecology and the Environment*, *9*(6), 351–357.

Flyvbjerg, B. (2004). Five Misunderstandings About Case Study Research. In C. S. G. Gobo, J. F. Gubrium, & D. Silverman (Eds.), *Qualitative Research Practice*, (pp. 420–434). Thousand Oaks, CA: Sage.

Larson, D. L., Phillips-Mao, Quiram, G., Sharpe, L. Stark, R., Sugita, S., & Weiler, A. (2011). A framework for sustainable invasive species management: Environmental, social and economic objectives. *Journal of Environmental Management*, *92*, 14–22.

Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., … Taylor, W. W. (2007). Complexity of Coupled Human and Natural Systems. *Science*, *317*, 1513–1516.

Spellman K. V., & Swenson, N. Y. (2012). Assessing the vulnerability of Western Alaska ecosystems and subsistence resources to non-native plant invasion. Western Alaska LCC Cooperative Project.

Vaske, J., & Manfredo, M. (2012). Social psychological considerations in wildlife management. In D. J. Decker, S. Riley & W. F. Siemer (Eds.), *Human dimensions of wildlife management,* (pp. 43–57). Baltimore, MD: The Johns Hopkins University Press.

Yokomizo, H., Possingham, H. P., Thomas, M. B., & Buckley, Y. M. (2009). Managing the impact of invasive species: the value of knowing the density–impact curve. *Ecological Applications*, *18*(2), 376–386.

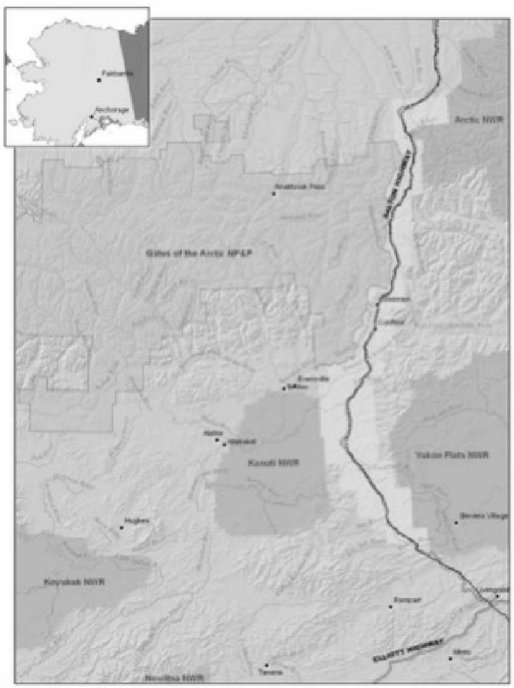
Appendix A. Survey Questionnaire

Thank you for your willingness to participate in this survey. The purpose of this research is to discover what you believe to be the best response to the spread of invasive bird vetch (*Vicia cracca*) along the Dalton Highway, north of the Arctic Circle.

Please take a moment and read the brief issue summary that follows. At the end, you will be asked a series of multiple choice questions. This should take no more than 10 minutes to complete. Your responses will be anonymous and any identifying information that you might choose to share will be kept confidential.

If you have questions or concerns about your rights as a research participant, you can contact the UAF Office of Research Integrity at 474-7800 (Fairbanks area) or 1-866-876-7800 (toll-free outside the Fairbanks area) or uaf-irb@alaska.edu.

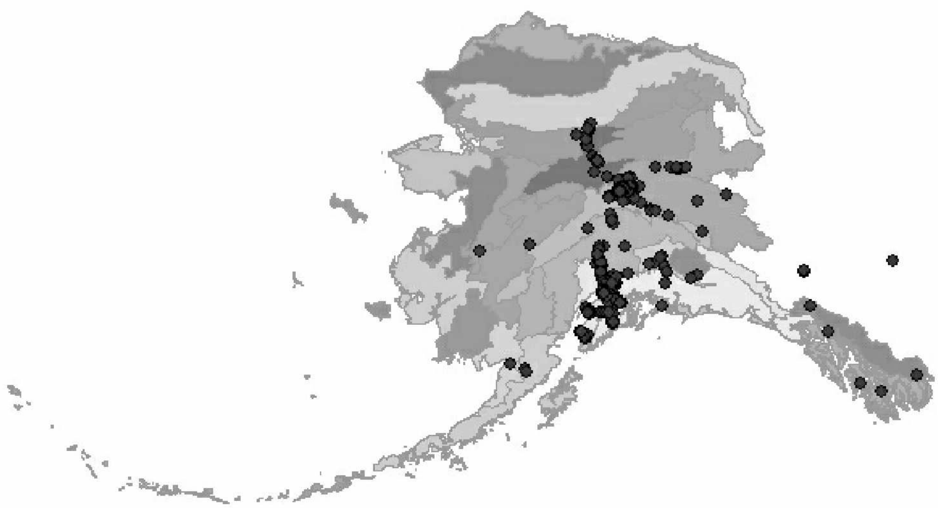
The Dalton Highway corridor borders a number of conservation areas such as Gates of the Arctic and Kanuti National Wildlife Refuge (shaded green and pink, respectively). The highway right-of-way is managed by the Bureau of Land Management (shaded yellow) and the road is maintained by the State of Alaska Department of Transportation.



The Dalton Highway is a heavily used utility road that runs north-south and crosses the Arctic Circle. Prior to construction in 1974, no roads connected the Alaska arctic to urbanized areas. When the Dalton Highway was open to the public in 1994, it became a gateway for recreation, commerce, mining, subsistence, tourism and subsequently, **invasive plants**.

Bird vetch is one such invasive plant species that has expanded its range north of the Yukon River along the Dalton Highway. Native to Europe, today bird vetch can be found throughout much of the U.S. and Canada.

Statewide bird vetch distribution (AKEPIC 2016)



First introduced to Alaska as a forage crop in Fairbanks and Palmer in the early 1900's, bird vetch has spread relatively slowly from these urban centers. Bird vetch was first documented north of the Yukon River in 2004 in populated areas of the Dalton Highway. In 2015, it was documented nearly 80 miles north of the Arctic Circle.

The characteristics that make bird vetch "invasive" are as follows:

- Fast growing
- Drought tolerant
- Cold hardy
- Forms dense mats
- Alters soil nutrient balance, particularly Nitrogen
- Climbs over and crowds out shade intolerant plants
- Changes snow drift patterns
- Engulfs grasses and small shrubs
- Competes with native field perennials

For complete information about Vicia *cracca* (Bird vetch) CLICK HERE

Bird vetch, like many invasive plant species, thrives in areas of both natural and human disturbance such as fire, floodplains, roads, pipelines or gravel pits.

Bird vetch at Dalton milepost 61 encroaching upon a roadside burn scar (Fort Hamlin Hills fire, 2004)

The transport of contaminated fill material for road maintenance and other activities is a potential contributor to the movement of bird vetch and other weedy species throughout the area.

Several infestations have been controlled manually by volunteers who have pulled them twice a year since 2008. These control actions have kept the infestations in check, yet there has been little detectable reduction in the size of the infestations (e.g. Rosie Creek, Fish Creek, Kanuti River).

Photo taken by Jerry D. McDonnell

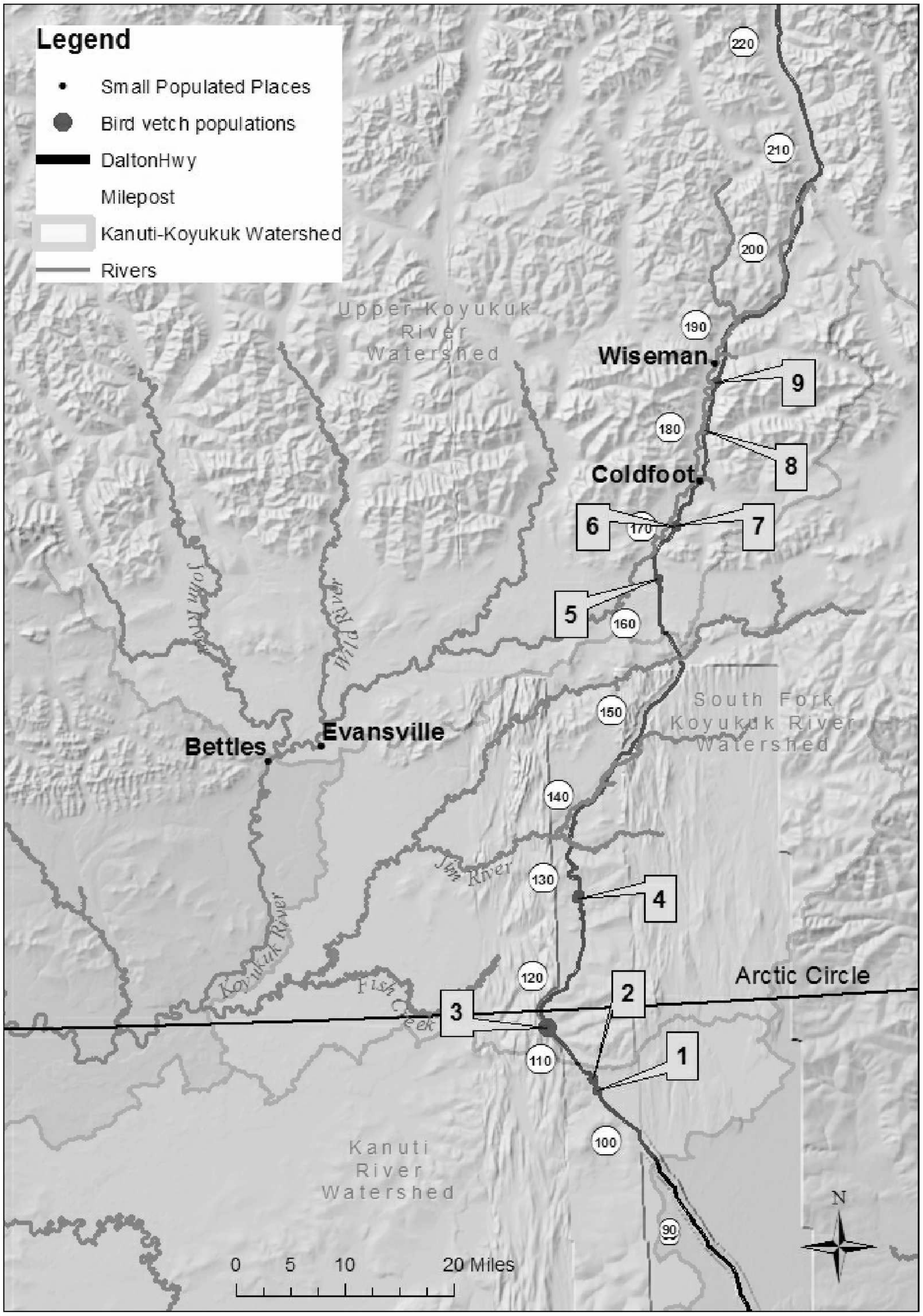
The seeds remain viable in the soil for up to 5 years. Both of these factors have positive implications for eradication if herbicides were to be used in combination with prevention.


I480853

To determine the scope of the infestation, Bureau of Land Management conducted a survey of bird vetch during the 2014 and 2015 field seasons. Roadsides and gravel pits were surveyed and the results are summarized below.

# Infested acres north of Arctic Circle	3.5 Acres
Average infestation size	0.6 Acres
# Distinct populations north of Arctic Circle	6
Northernmost Dalton Highway infestation	MP 184

The following is a map the of distinct populations (>1000 feet apart) of bird vetch along the Dalton Highway north of the Arctic Circle (AKEPIC 2016)


Legend
Small Populated Places
Bird vetch populations
DaltonHwy
Milepost
Kanuti-Koyukuk Watershed
Rivers
Upper Koyukuk River Watershed
South Fork Koyukuk River Watershed
Kanuti River Watershed
Wiseman
Coldfoot
Bettles
Evansville
Arctic Circle
John River
Wild River
Jim River
Koyukuk River
Fish Creek
1
2
3
4
5
6
7
8
9
90
100
110
120
130
140
150
160
170
180
190
200
210
220
0 5 10 20 Miles
N

A control strategy is in place for the Dalton Highway corridor The document provides guidance for the use of EPA-approved herbicides and outlines important prevention methods. It also requires strict compliance with safe application and monitoring practices to minimize impacts to the environment and humans.

For instance, herbicides would NOT be applied within:

- 200 feet of any surface water or floodplain of essential fish habitat
- 200 foot buffer around drinking water wells
- 1/2 mile radius of the community of Wiseman(no infestations known to be established in Wiseman)

Other requirements for herbicide use include:

- Point specific application (see image)
- Water quality monitoring
- Post treatment infestation monitoring
- Public notifications of herbicide use

Photo example of **point specific application** taken by Alaska Department of Environmental Conservation Certified Pesticide Applicator Program

The human and environmental effects of using these herbicides have been evaluated through the NEPA process. Approved for use in this case, and effective on bird vetch in Alaska, is the herbicide clopyralid (i.e. Transline), which is a "selective" chemical that kills only broad-leaved plants. **The treated site would need to be revisited every six weeks until winter and the treatment repeated for five years.**

To read the complete label, CLICK HERE

A2A / Transline / Amend / 04-20-15

ACCEPTED
04/23/2015
Under the Federal Insecticide, Fungicide and Rodenticide Act as amended, for the pesticide registered under EPA Reg. No. 62719-259

Page 1

(Base label):

Transline®

SPECIALTY HERBICIDE

- For control of broadleaf annual and perennial weeds and woody brush species on: rangeland and permanent grass pastures, grasses grown for hay, Conservation Reserve Program (CRP) sites;
- forest sites, conifer and tree plantations;
- non-crop areas for example airports, barrow ditches, communication transmission lines, electrical power and utility rights-of-way, fencerows, gravel pits, industrial sites, manufacturing and storage sites, military lands, mining and drilling areas, non-irrigation ditch banks, oil and gas pads, parking lots, petroleum tank farms, pipelines, railroads, roadsides, storm water retention areas, substations, unimproved rough turf grasses, vacant lots and other non-crop residential areas, and around farm buildings;
- natural areas (open space) for example, campgrounds, parks, prairie management, trails and trailheads, recreation areas, wildlife openings and wildlife habitat and management areas;,
- including grazed areas on these sites .

Active Ingredient:
clopyralid: 3,6-dichloro-2-pyridinecarboxylic acid, monoethanolamine salt 40.9%
Other Ingredients 59.1%
Total 100.0%

Acid Equivalent:
3,6-dichloro-2-pyridinecarboxylic acid - 31% (3 lb/gal)

Keep Out of Reach of Children

CAUTION

Precautionary Statements

Hazards to Humans and Domestic Animals

Causes Moderate Eye Irritation • Harmful If Absorbed Through Skin

Avoid contact with eyes, skin or clothing. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, or using tobacco. Remove and wash contaminated clothing before reuse.

Personal Protective Equipment (PPE)

Applicators and other handlers must wear:
- Long-sleeved shirt and long pants
- Chemical-resistant gloves made of any waterproof material
- Shoes plus socks

IF control actions were conducted as described herein and combined with prevention and monitoring...

Would you be in favor of using herbicides to control of bird vetch populations north of the Arctic Circle along the Dalton Highway over the course of the next five years?

- ◯ Yes, very certain
- ◯ Yes, somewhat certain
- ◯ Neither yes or no
- ◯ No, somewhat certain
- ◯ No, very certain

How likely is it that IN THIS CASE the use of herbicides will result in...

	Highly likely	Moderately likely	Somewhat likely	Neither likely or unlikely	Somewhat unlikely	Moderately unlikely	Highly unlikely
...impacts to human health due to contamination of subsistence resources	◯	◯	◯	◯	◯	◯	◯
...impacts to wildlife health	◯	◯	◯	◯	◯	◯	◯
...the contamination of water resources due to leaching	◯	◯	◯	◯	◯	◯	◯
...the introduction of new invasive plants after treatment	◯	◯	◯	◯	◯	◯	◯
...an accumulation of dead vegetation after treatment	◯	◯	◯	◯	◯	◯	◯
...the eradication of bird vetch north of the Arctic Circle	◯	◯	◯	◯	◯	◯	◯
...the loss of insulative cover for permafrost where bird vetch has been removed	◯	◯	◯	◯	◯	◯	◯
...persistence of herbicidal formulations in the Arctic environment	◯	◯	◯	◯	◯	◯	◯
...cost effective outcomes in the long term	◯	◯	◯	◯	◯	◯	◯
...harm to nearby native plants	◯	◯	◯	◯	◯	◯	◯
...the cost of treatment will outweigh the benefits of eradication	◯	◯	◯	◯	◯	◯	◯

If each of the following outcomes were to occur as a result of using herbicides, how acceptable would it be in this case?

	Highly acceptable	Moderately acceptable	Somewhat acceptable	Neither acceptable or unacceptable	Somewhat unacceptable	Moderately unacceptable	Highly unacceptable
...impacts to human health due to contamination of subsistence resources	○	○	○	○	○	○	○
...impacts to wildlife health	○	○	○	○	○	○	○
...the contamination water resources due to leaching	○	○	○	○	○	○	○
...the introduction of new invasive plants after treatment	○	○	○	○	○	○	○
...an accumulation of dead vegetation after treatment	○	○	○	○	○	○	○
...the eradication of bird vetch north of the Arctic Circle	○	○	○	○	○	○	○
...the loss of insulative cover for permafrost where native vegetation has been eliminated	○	○	○	○	○	○	○
...persistence of herbicidal formulations in the Arctic environment	○	○	○	○	○	○	○
...cost effective outcomes in the long term	○	○	○	○	○	○	○
...harm to nearby native plants	○	○	○	○	○	○	○
...the cost of treatment will outweigh the benefits of eradication	○	○	○	○	○	○	○

Thank you for your participation in this survey. Please take a moment to provide any feedback below.

Prior to taking this survey, were you aware that bird had become established north of the Arctic Circle?

- Yes
- Neither yes or no
- No

Please indicate from the options below, what best describes your interest in this issue?

- Transportation
- Utility and Infrastructure
- Conservation professional
- Concerned citizen
- Researcher
- Other (please specify)

Comments?

Appendix B. Institutional Review Board

CITI Collaborative Institutional Training Initiative

Human Research Curriculum Completion Report
Printed on 10/18/2011

Learner: Tara Callear (username: taracallear)
Institution: University of Alaska, Fairbanks
Contact Information 1902 Central Ave
Fairbanks, AK 99701
Department: Department of Natural Resources
Phone: 907-699-6808
Email: taracallear@gmail.com

Social Behavioral Research Investigators and Key Personnel:

Stage 1. Basic Course Passed on 10/18/11 (Ref # 6894026)

Required Modules	Date Completed	
Introduction	10/18/11	no quiz
History and Ethical Principles - SBR	10/18/11	4/4 (100%)
The Regulations and The Social and Behavioral Sciences - SBR	10/18/11	5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR	10/18/11	5/5 (100%)
Informed Consent - SBR	10/18/11	4/5 (80%)
Privacy and Confidentiality - SBR	10/18/11	5/5 (100%)
Avoiding Group Harms: U.S. Research Perspectives	10/18/11	3/3 (100%)
Conflicts of Interest in Research Involving Human Subjects	10/18/11	4/5 (80%)
University of Alaska - Fairbanks	10/18/11	no quiz

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

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