INVASIVE SPECIES ON BRITISH COLUMBIA'S GRASSLANDS: ESTIMATING THE BENEFITS OF CONTROL POLICIES.

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE
IN
ENVIRONMENTAL SCIENCE

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Abstract

Invasive species are among the most important drivers of biodiversity loss and changes in ecosystem services leading to substantial worldwide economic and ecological damages. The invasion of grasslands by non-native plant species imposes a wide range of costs on society; these costs are associated with a reduction in biodiversity, wildlife habitat loss, and impacts on recreational opportunities, amongst other ecosystem services. Damage reductions need to be examined when establishing control programs and public policy. Inadequate information on invasive plants' economic impacts and the extent to which they affect human welfare has created a significant barrier to implementing comprehensive national invasive species management programs. This study examines people's attitudes and perceptions of the problem of invasive plant species on grasslands in British Columbia (B.C.) using a choice experiment. The results of the choice experiment indicate how much respondents are willing to pay for various attributes of a control policy, such as location, method of control, and degree of control for invasive plant species in B.C. It also determines how much respondents are willing to pay for different policy packages (combinations of the control attributes) to control invasive plant species. Results from 1,000 respondents across B.C. indicate serious concern and a willingness to pay to control the problem. Preference is given to control everywhere in the interior of B.C. (where most grasslands are located) relative to only control in sub-regions of the interior. Biological and targeted grazing are preferred to chemical spraying and moderate or major eradication relative to minor eradication. Estimates indicate that, at the minimum, British Columbians are willing to pay around CDN$200 million per year in extra taxes to control invasive plant species everywhere in the interior of B.C. with a moderate or major eradication over the next decade using chemical spraying. Using biological or targeted grazing, the valuation doubles to around CDN$400 million annually. These values are estimates of the aggregate benefits of controlling invasive species in B.C.'s grasslands, but not the costs of controlling nor the productivity of the control measures, which would be needed to conduct a cost-benefit analysis. Furthermore, to bridge the gap between public preferences and experts' opinions regarding priorities in invasive species control programs, the survey was circulated to a group of experts and stakeholders and the results were contrasted with the results of the public survey. Lastly, the thesis provides a coherent framework for the sustainable prevention and management of non-native invasive plants in B.C.

DEDICATION

To my husband, Barrister Akinloye Ajayi, who approved and allowed me to apply for this program, thank you for the opportunity to follow my passion. I love you so much. Thank you for supporting me financially, emotionally, and spiritually. God bless you.

Also, to my children Iyanuoluwa, Temiloluwa, and Ibukunoluwa Ajayi, thank you all for your endless support and for enduring all those endless nights of studying.

I dedicate this thesis to my Lord Jesus Christ, my source of life, the Author and Finisher of my faith.

ACKNOWLEDGMENTS

I would first like to acknowledge my supervisor, Dr. Lauchlan Fraser. Thank you for accepting to be my supervisor. Your willingness, support, and guidance made this project possible.

Also, my appreciation goes to Dr. Peter Tsigaris, my able supervisor. I have grown and learned so much from you over the last two years, and I could not have achieved this feat without your support, encouragement, investment, and dedication to my thesis. I am eternally grateful. To my thesis committee member Dr. Joel Wood, I appreciate your valuable suggestions and feedback throughout my graduate studies.

I want to thank Dr. Solomon Geleta for accepting to be my external examiner, I appreciate your contribution towards the success of my thesis defence.

I would also like to thank Dr. Nick Hanley, Dr. John Janmaat, and Dr. Michael Springborn for their invaluable contributions to this thesis.

Lastly, I want to acknowledge all the research assistants, graduate students, and postdoctoral fellows of the Fraser Lab who have helped me throughout my time as a student in the lab.

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CHAPTER 1: INTRODUCTION

Invasive species are non-native or alien species that, upon introduction to an ecosystem, cause or have the potential to cause economic or environmental harm, including harm to human and animal health (Convention on Biological Diversity, 2002). They can disrupt ecosystems, increase the risk of species extinction, and cause significant economic damage (Gurevitch & Padilla, 2004). In addition, invasive species can cause harm to native ecosystems, including grasslands, and the ecological services they provide to humanity. Examples of the ecosystem services provided by grasslands include provisioning services such as food, water, and raw materials, regulating and maintenance services such as air quality regulation, climate regulation, regulation of water flow, pollination, and cultural services such as recreation and tourism, aesthetic beauty, spiritual experience, etc. (Jones, 2017; Kaiser, 1999; Pejchar & Mooney, 2009). As the problems of invasive species keep growing worldwide, more studies are being carried out to track their impacts and develop ways of keeping them in check (Hobbs, 2000; Rejmánek et al., 2005).

Grasslands, covering approximately one-third of the Earth's terrestrial surface, are vital ecosystems that support a diverse range of plant and animal species (Kemp & Michalk, 2007; Tisdale, 1947). In British Columbia (B.C.), native grasslands comprise less than 1%, 0.74 million ha of the total landmass but harbor more threatened and endangered species than other habitat types (Grassland Conservation Council of B.C., 2002). Grasslands are primarily found in the dry interior and eastern side of the province, occupying areas with hot summers and low precipitation levels. B.C.'s grasslands can be divided into semi-arid grasslands south of 52 degrees northern latitude and cool grasslands north of 52 degrees (Winnicki et al., 2020). About 2,854 vascular plants occur in B.C., with approximately 42% occurring in grasslands (Wikeem & Wikeem, 2004). Unfortunately, a significant portion of B.C.'s grassland ecosystems, approximately 35%, are dominated by non-native herbaceous vegetation (Gayton, 2004). The threats to grasslands include the planting of non-native pastures and crops, changes in fire regimes, and invasive weeds (Keeley, 2006). Preserving grasslands is crucial for maintaining species diversity and ecosystem services (Bengtsson, 2019), as they contribute to climate regulation, aesthetic appeal, pollination, food production, and conservation value (Hanisch et al., 2020).

B.C.'s grassland ecosystems face severe threats (Pitt & Hooper, 1994; Branch, 2004). Most endangered species in the province rely on these habitats. Most of these species become endangered because of the loss or fragmentation of their habitats, mainly due to disturbances caused by humans (Gayton, 2004; Branch, 2004). Grasslands in B.C. are affected by both “natural” and human disturbances. Natural disturbances such as floods, fires, landslides, and windstorms affect grasslands. In contrast, human-induced disturbances like agriculture, urban development, recreation, and grazing have significantly reduced grassland size and altered the ecosystem (Grassland Conservation Council, 2002). Agricultural activities, including hay production and cultivation of various crops, including vineyards, have removed substantial amounts of native grassland vegetation and impacted soil structure (Grassland Conservation Council, 2002). Urban development has led to the conversion of grasslands into developed areas, further limiting the available habitat. Forest encroachment is also a concern, as trees have expanded into grasslands, reducing grazing areas for livestock and wildlife (Grassland Conservation Council, 2002).

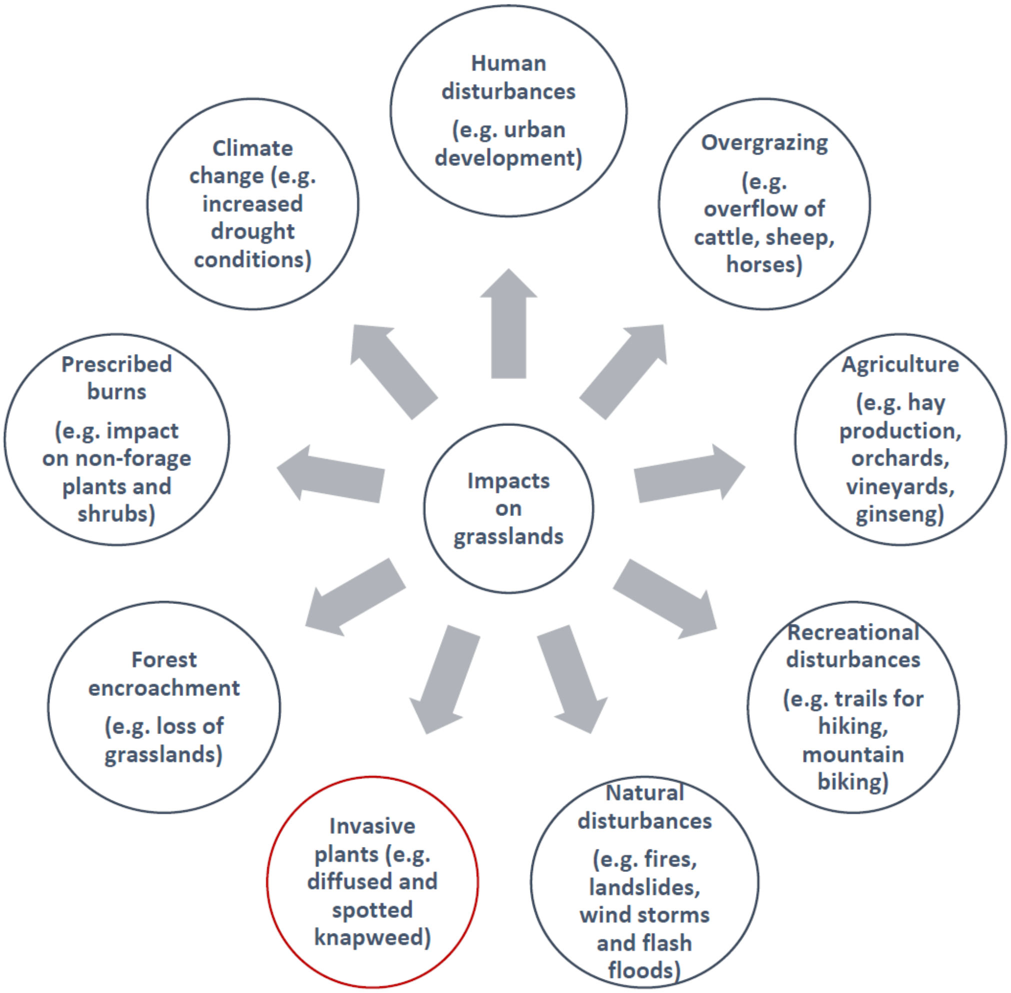

Figure 1.1: Various disturbances on grasslands

Invasive plants on B.C.'s grasslands

As of 1995, non-native invasive plants in B.C. had invaded over 100,000 hectares (ha) of grasslands and open forests and another 10 million ha susceptible to invasion; by 2010, over 200,000 hectares had been infested by invasive plants, with another 20 million hectares of Crown land susceptible to invasion. (Follow-up report: Update on control of invasive plants, 2010). Over 70 species of invasive plants were discovered on 189 protected lands surveyed in B.C., and around 98% of protected lands possess invasive plants (Miller & Wikeem, 2005). The introduction and spread of non-native invasive species remain the greatest threat to natural grasslands in B.C. (Dennehy et al., 2011; Gaskin et al., 2021). Non-native invasives typically do not have natural enemies outside their range that would otherwise control their spread (White & Schwarz, 1998). They also possess plant traits encouraging their spread and dominance, such as fast growth and producing many tiny, wind-borne seeds (White & Schwarz, 1998). They compete for moisture and soil nutrients with native species and are usually not predated by wildlife or livestock. Non-native species reduce the biodiversity of grasslands and are generally very difficult to control once established (Sagoff, 2005; Hejda et al., 2009; Manchester & Bullock, 2000). The introduction of non-native invasive plant species into B.C.'s grasslands is usually through seeds in imported hay, imported livestock feed, and programs re-seeding grassland (Grassland Conservation Council of B.C., 2002). Fourteen plant species listed as noxious weeds in the B.C. Weed Control Act are the following. (See Appendix B for the description)

- Spotted knapweed (*Centaurea maculosa*)
- Diffuse knapweed (*Centaurea diffusa*)
- Hounds-tongue (*Cynoglossum officinale*)
- Dalmatian toadflax (*Linaria dalmatica*)
- Rush skeletonweed (*Chondrilla juncea*)
- Leafy spurge (*Euphorbia esula*)
- Sulphur cinquefoil (*Potentilla recta*)
- Scentless chamomile (*Matricaria maritima*)
- Tansy ragwort (*Senecia jacobaea*)
- Oxeye daisy (*Chrysanthemum leucanthemum*)
- Orange hawkweed (*Heiracium aurantiacum*)
- Yellow hawkweed (*Heiracium pratense*)

Grassland ecosystem services and impacts of invasive plant species.

Grassland ecosystems provide many valuable services to the environment and human society. These services, known as ecosystem services, are the benefits people obtain from ecosystem functioning (Barbier et al., 2009; Brussaard, 2012; Granek et al., 2010). Some critical ecosystem services provided by grasslands include:

1. Carbon sequestration(CS): CS by grasslands reduces climate change. Grasses use their roots to store carbon in the soil, reducing greenhouse gas emissions and global warming (Fornara et al., 2010; O'Mara, 2012).
2. Biodiversity: Grasslands host many species. Many insects, birds, reptiles, and mammals are adapted to these habitats. The grassland ecosystem's resilience and ecological processes depend on biodiversity (Habel et al., 2013; Van- Oijen et al., 2018).
3. Soil Conservation: Grassland vegetation reduces topsoil erosion and improves soil fertility. Roots of grasses bind the soil together, preventing erosion (Reubens et al., 2007; Lee et al., 2021).

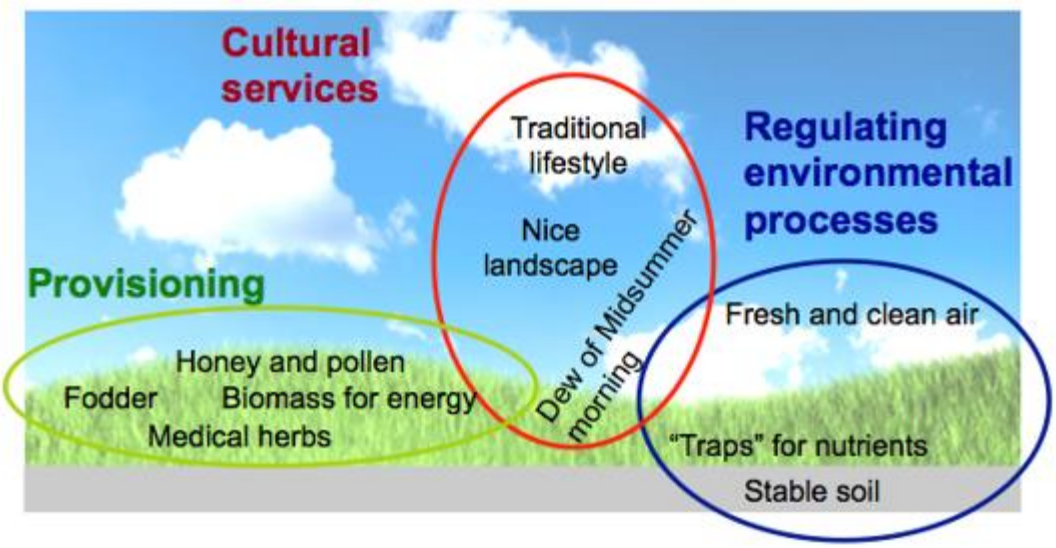

Figure 1.2: Attribution: https://vivagrass.eu/ecosystem-services/

4. Water Filtration and Regulation: Grasslands filter water and recharge aquifers. They absorb rainfall and reduce runoff, preventing floods and stabilizing streamflow. Grasslands also remove pollutants and debris from water (Dissmeyer, 2000).

5. Pollination: Insect pollinators reproduce many grasslands flowering plants. Bees, butterflies, and other pollinators need grassland ecosystems to pollinate adjacent crops and wildflowers(Batáry et al., 2010; Clough et al., 2014).
6. Livestock Forage: Grasslands feed cattle, sheep, and other domestic animals. These environments provide livestock-supporting grasses and herbs (Kemp et al., 2013; O'Mara, 2012).
7. Cultural and Recreational Values: People value grasslands. Beautiful scenery, outdoor leisure, and nature enjoyment like birdwatching, hiking, and photography are available (Sala & Paruelo, 1997; Bengtsson et al., 2019). Indigenous peoples value grasslands spiritually.

Table 1.1:Ecosystem services provided by grasslands.

Service Type	**Ecosystem Services**	**Examples from grassland biome**
Provisioning	Food Water Raw materials Medicinal and genetic resources Ornamental resources	Grains, e.g., oat, barley, etc., prairie potholes, Vernal pools, streams, Medicinal plants, cosmetics, fodder
Regulating and maintenance	Air quality regulation Climate regulation Regulation of water flow Pollination Waste treatment Erosion Prevention Moderation of extreme events Biological control Maintenance of soil fertility Maintenance of life cycles Maintenance of genetic diversity	Carbon sequestration, dust trapping, greenhouse gas regulation, protection of watersheds, streams, and rivers; pollution control, detoxification of wastes; soil erosion protection, cycling and movement of soil nutrients, herbivory control
Cultural	Aesthetic beauty Recreation and tourism Inspiration for culture, art, and design Spiritual Experience Information for cognitive development Existence, bequest values	Grassland aesthetic beauty, Outdoor recreational activities

Sala & Paruelo, 1997; Bengtsson et al., 2019; Zhao, 2020

The impacts of invasive plants on grassland ecosystems are far-reaching. They can modify ecosystem structure, decrease diversity, and alter ecosystem functions (Cuddington & Hastings, 2009; Hedja et al., 2009). They can also affect the hydrological balance of water in the ecosystem, increase soil erosion, decrease native plant diversity, and alter fire regimes (Brooks et al., 2004; Dukes & Mooney, 2004). Invasive species can also alter carbon, nitrogen, and hydrologic cycles, and changes to these terrestrial cycles can ultimately affect water quality and quantity. (Table 1.1)

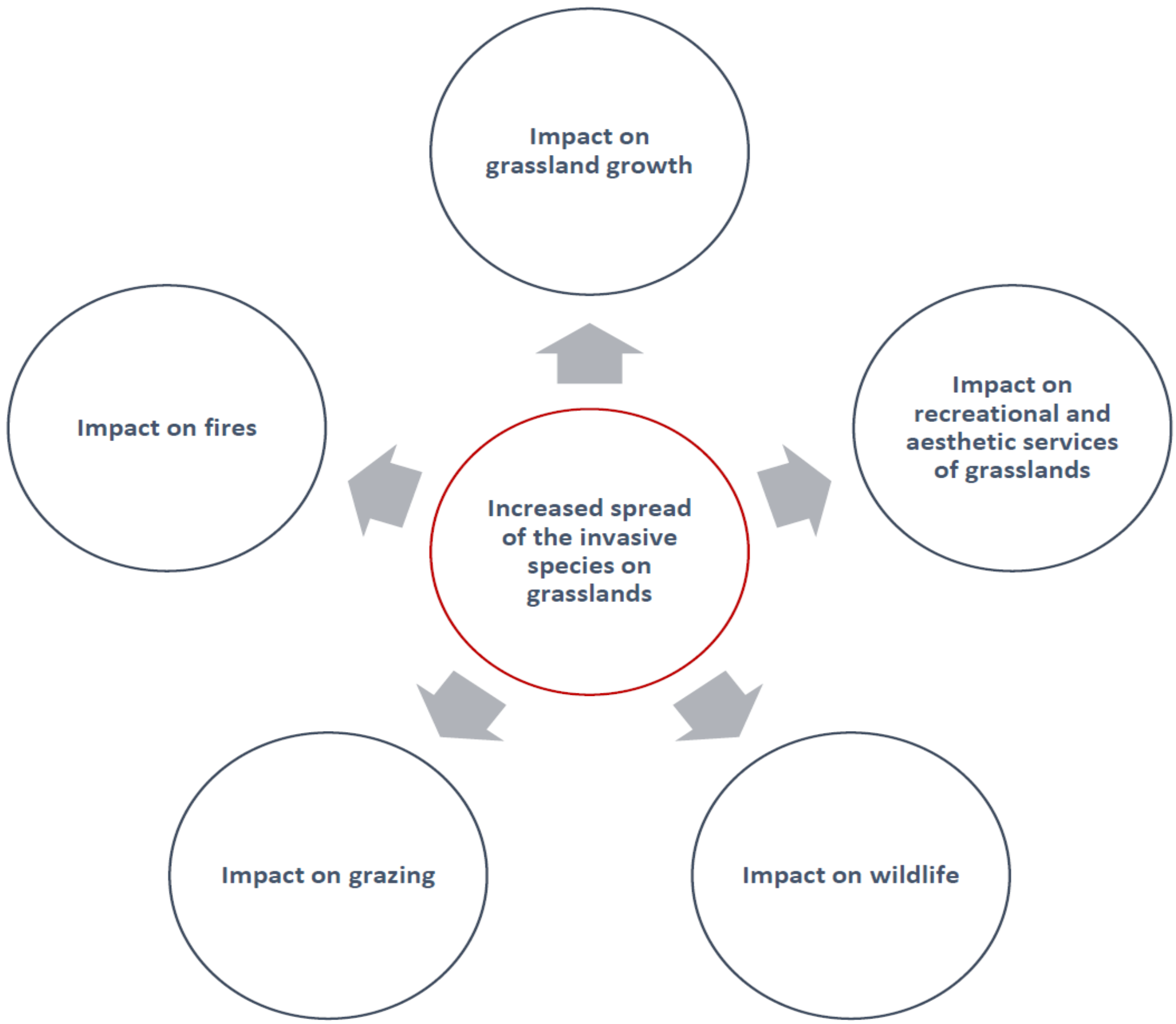

Figure 1.3: The various impacts of invasive species on grasslands.

Impacts of invasive plant species on carbon and nitrogen cycling on grasslands

Most studies agree that invasive plant species increase ecosystem productivity by enhancing carbon sequestration and cycling; the result can vary depending on the ecosystem invaded and the climate involved (Liao et al., 2008). The rate of nitrogen cycling can be increased in the soil by invasive plants in grasslands and forests (Lovett et al., 2010). The soil's nitrogen and carbon cycle changes can affect the hydrological balance as invasive species use more water than native plants, resulting in lower soil moisture. (Cavaleri & Saek, 2010; Pysek et al., 2012). The indirect effect of invasive plant species can be observed on the hydrological balance, especially when the invasive plants are physiologically and phonologically different from the native plants (Baer et al., 2006; Brantley et al., 2015).

The invasion of grasslands by invasive species is known to impact nutrient cycling, with increased above-ground nitrogen and soil nitrogen availability; this tends to stimulate microbial activities and increase the availability of inorganic nitrogen in invaded soils leading to an increase in the strength of the invasive plants (Castro-Diez et al., 2014; Ehrenfeld et al., 2005; Liao et al., 2008).

Impacts of invasive plants on water quality and quantity.

The addition of new plant exudates and increased nutrient leaching due to altered biogeochemical cycles (Chamier et al., 2012; Nagler et al., 2008; Ehrenfeld et al., 2003). Invasive plant species cause an increase in the concentration of water-soluble nutrients, increase the rate of nutrient leaching, and generally elevate nutrient concentration in both ground and surface waters. Symbiotic nitrogen-fixing invasive plant species cause the most significant effect on water quality, as they increase the rate of nitrogen input in the ecosystems and soil water nitrogen (Baer et al., 2006; Goldstein et al.,2010). Increasing nitrogen inputs may also aggravate soil acidification resulting in increased leaching of cations into groundwater and surface water (Matson et al.,1999). The presence of invasive plants can also impact water quantity in terrestrial ecosystems. Invasive plants use the process of evapotranspiration (ET) to affect water quantity in the soil. The conversion from native species to non-native invasive plant species in grassland and forest ecosystems causes a substantial (> 10%) reduction in streamflow (Jain et al., 2015). Invasive plants' greater water use can alter the groundwater dynamics (Saha et al., 2015).

Socio-economic impacts of invasive species

The social and economic impacts of invasive species are extensive. They can directly affect property values, agricultural productivity, public utilities, native fisheries, tourism, and outdoor recreation and incur costs associated with invasive species control efforts (Perrings et al., 2002). Invasive species are often linked to economic activities' intended or unintended consequences (Perrings et al., 2002). Invasive species significantly impact landscapes, ecosystems, and biodiversity levels (Baskin, 2002). Therefore, it is crucial to consider economic applications to understand the problem and accurately assess the benefits and costs of control alternatives (Pimentel et al., 2001).

Invasive species can also affect human well-being negatively and positively. These invasions must be evaluated to investigate their impact on the socio-ecological and socio-economic aspects of human existence. Biodiversity loss induced by invasion usually alters temperature and other climatic factors, negatively affecting public health (Jones, 2017). Ornamental invasive species introduced into the ecosystem either deliberately or accidentally adversely affect human and ecosystem health (Rai, 2015). The destructive abilities of invasive species on the natural environment could significantly reduce human quality of life, affecting individuals' subjective well-being. According to Shackleton et al. (2019), invasive species not only negatively impact livelihoods but could also be beneficial to the overall well-being of local livelihood; for example, some invasive plant species could serve as fuelwood, fodder, timber, and food products for local households. Additionally, invasive species may have cultural and economic value, providing opportunities for recreation, spiritual value, and income generation.

Economic costs of invasive species

Ecosystems provide humans with goods and services they value. Invasive species can become harmful to natural ecosystems and their values. These values could either be use or non-use values. A loss of these values imposes a loss of well-being on individuals and societies and should be considered when making policy decisions. Economics helps develop invasive species management strategies and policy formations by providing reliable estimates of the benefits (in terms of damage avoided) and costs of controlling the invasions (Hanley & Roberts, 2018). Despite the importance of these estimates, they are difficult to come by due to the scope of and complexities involved in the invasive species management problem, creating several challenges for calculating the cost-benefit analysis of control.

Rising economic costs of biological invasions worldwide.

Biological invasions have been associated with substantial economic losses and management expenditures globally. To effectively mitigate the effect of these invasive species, a reliable estimate of the global economic costs associated with these impacts needs to be developed. To achieve this, the Invacost database has been developed, which provides an up-to-date, comprehensive, and harmonized compilation and description of economic cost estimates associated with biological invasions worldwide (Diagne et al., 2020). According to this database, the reported cost of the invasion reached a minimum of US$1.288 trillion (2017 U.S. Dollars) over the past few decades (1970 – 2017), with an annual mean cost of US$26.8 billion and reached US$162.7 billion in 2017 (Diagne et al.,2020). These costs remain strongly underestimated and do not show any sign of slowing down, exhibiting a consistent three-fold increase per decade (Diagne et al., 2020). The comprehensive database of the economic costs of invasive insects shows that taking all reported goods and service estimates, invasive insects cost a minimum of US$70.0 billion per year globally, while associated health costs exceed US$6.9 billion per year. The lack of dedicated studies, especially for reproducible goods and service estimates, implies a gross underestimation of global costs (Bradshaw et al., 2016).

Cost estimates at national levels are crucial, as they can duly inform management policies. Several nations have made attempts to estimate the damage caused by invasive species. In the 2009 project report by Frid et al. titled "Economic impacts of invasive plants in British Columbia," the total expected damages, in the absence of any management, were estimated to be a minimum of CA$65 million in 2008, rising to CA$139 million by 2020. These values are likely underestimates, as economic data were unavailable for all potential impacts.

Pimentel et al. (2005) evaluate the magnitude of the environmental impacts and economic costs associated with the diverse alien species established within the United States. The evaluation is limited to exotic species not originating within the United States or its territories, although translocated species can also have significant impacts. The study shows that economic damages associated with alien invasive species effects and control amount to approximately US$120 billion annually.

Ecosystem services are not exempted from the devastating effects of invasive species. Invasive species can trigger a massive loss of ecosystem services through a trophic cascade. The economic damage of the degradation caused by spiny fleas to water clarity, a valuable ecosystem service, was estimated in the U.S. The cost of reinstating water clarity lies between US$86.5 million and US$163 million; this cost is equivalent to the cost of the service itself, US$140 million, which is the amount people are willing to pay for water clarity as a service. Time series modeling showed that the loss in water clarity valued at US$140 million (US$640 per household) could be reversed by a 71% reduction in phosphorus loading. The reduction of this magnitude is estimated to cost between US$86.5 million and US$163 million (US$430 to US$810 per household); this requires increased investment in preventing and controlling invasive species (Walsh et al., 2016).

Control measures for invasive species.

It can be difficult to control invasive plant species; various techniques must be employed to achieve this effectively. Some standard methods for managing and controlling invasive plant species include:

1. Prompt identification and action against invasive plant species are essential to stopping their establishment and spread. Regular monitoring and surveillance programs can assist in the early detection of invasive plants, enabling the quick and precise application of control measures (Shesley et al., 1996; DiTomaso, 2000).
2. Mechanical control: This technique involves physically removing invasive plant species, either using hands, mowing, cutting, or uprooting the whole plant from the soil. Mechanical control could be economically and ecologically advantageous because it could be cheaper and more environmentally friendly than other methods, especially chemical control (Astrand & Baerveldt, 2001).

3. Biological control: This is done by introducing the invasive plants' natural enemies or biological agents to infested areas. The biological agents are used to reduce the population of invasive plants to ecologically or economically acceptable levels. Examples include insects, parasites, predators, or pathogens. Caution must be taken to ensure the introduced bioagents do not harm the native ecosystem or plants (Kennedy, 1999).
4. Chemical control: This involves using synthetic and naturally derived herbicides to control the population of invasive plants. It is best used for vast expanses of infested areas. Herbicides are applied selectively to target specific invasive plants while minimizing the effect on native plants and the ecosystem. Herbicides are one of the most efficient short-term methods of controlling invasive species, and they are important in boosting outputs (Barrons, 1969).
5. Targeted grazing: Animals like cattle, sheep, and goats have been utilized to combat invasive plant species on grasslands (McSherry & Ritchie., 2013). Sheep and goats are more commonly used since they can consume plants rejected by cattle. Before animals can be used as a control agent for invasive plants, the plant's timing and stage of development must be considered because animals eat plants at different stages of their life (Popay & Field, 1996).
6. Integrated pest management (IPM): This approach combines different control methods to attack and control invasive plant species. It involves assessing the state and rate of infestation and choosing a combination of appropriate strategies that minimize environmental harm while also containing invasive plants.

The method to use in combating invasive plants depends on various factors. The type of invasive plants, the scale of infestation, the kind of ecosystem, and the available resources must all be considered before implementing any control measure. IPM has been suggested to be the most effective way of controlling invasive plants (Buckley et al., 2004; Miller et al., 1992).

Methods for valuing non-market impacts of ecosystem services.

Values attached to an environmental good or service which cannot be priced in the market are usually estimated using non-market valuation methods, e.g., the non-market impact of invasive species, grassland conservation, and air quality changes. Non-market valuation methods are categorized into three types (Hanley & Barber, 2009)

- Stated preference approaches.
- Revealed preference approaches.
- Production function methods.

All these methods rely on the maximum willingness to pay as a standard measure of a good's economic value to an individual. The amount an individual is willing to give up to obtain a good determines how much he values the good. Stated and revealed preference approaches estimate the effect of environmental changes on human well-being, i.e., they estimate the direct effect on utility. (Table 1.2). There are two main stated preference methods: contingent valuation and choice experiments (or choice modelling) (Hanley & Czajkowski, 2017).

In contingent valuation, survey respondents decide whether they agree to a change in how much of an environmental good is provided at a specific cost, e.g., paying $45 to delay the arrival of knapweed to a specific grassland and maintain the recreational ability of the biome. (McIntosh et al., 2010). In choice experiments, choices are made between different bundles or alternatives of environmental goods (e.g., various options of invasive species control) by relying on the attributes of this good (e.g., type of control, ownership of grassland). A choice experiment asks respondents to choose between different bundles of environmental attributes; this allows the researcher to infer what economic value they place on these attributes (Hoyos, 2010).

Table 1.2: Methods of valuing ecosystem services from grasslands.

Valuation Methods	Description
Choice experiment (modeling)	Deciding on the trade-offs between ecosystem services to elicit willingness to pay to control invasive species on grasslands
Contingent valuation	Stating willingness to pay to control invasive species on grasslands
Damage costs avoided	Estimated damage avoided from control system relative to business as usual
Defensive expenditure	Expenditure to protect grasslands by ranchers and government
Market price approach	Prices for ecosystem services provided by grasslands observed in markets
Opportunity cost	Using the next highest value use of grasslands
Production function	Estimation of the production function for marketed goods provided by the grasslands
Restoration cost	Estimate the cost of restoring the degraded ecosystems of grassland to provide the ecosystem services.
Benefit Transfer method	Estimate the benefit of ecosystem services at the grasslands site before and after the invasive species using existing information from different study site(s)
Travel Cost Method	Estimate the value of recreational benefits of grasslands.
Hedonic Pricing	Estimate the value of environmental amenities that affect prices of marketed goods, such as housing prices.

Carson & Bergstrom, 2003; Farber et al., 2002; *Folkersen, 2018*

Choice experiments have been used in environmental and conservation management contexts (Roberts et al., 2017). People make choices between different combinations of environmental goods; this could include various measures for invasive species control, which is presented as a function of the attributes of the good (e.g., forest ownership, type of forest, control action). One of these attributes contains the cost of providing the good (e.g., an increase in the annual fee for membership of a reserved park, local tax increment). One of the attributes of the good, which people could make choices from, is the population of an invasive species or the effect of a species on an ecosystem. Researchers can use choice experiments to discover aspects of a control program most valued by citizens (Rolfe & Windle, 2014). For example, a choice experiment has been used in many environmental and conservational management programs (Roberts et al., 2018). A significant disadvantage of the stated preference method, including choice experiments, is that they are not based on actual payment for the good or service. However, they offer many benefits, such as widespread applicability and the ability to measure non-use and use values (Hanley & Barbier, 2009).

Willingness to pay for the control of invasive species.

Several studies have investigated the willingness to pay (WTP) to control invasive species in different contexts. Chakir et al. (2016) used the choice experiments approach to measure the WTP of the French population to preserve native biodiversity and reduce the nuisance caused by the Asian ladybird invasive species. The study found that people were willing to pay to protect native species, decrease pesticide use, and reduce the adverse effects of Asian ladybirds on households.

Sheremet et al. (2017) examined public preferences and WTP for forest disease control in the UK. The study found that disease control programs in publicly owned forests and forests owned by charitable trusts were more likely to receive public support. Case studies examining the willingness to pay for invasive species control have highlighted the importance of considering public preferences and the economic benefits of managing invasive species. Adams et al. (2020) used the choice experiment to estimate how much residents of Florida are willing to pay monthly to protect their urban forests against invasive pests. The residents were willing to pay an average of US $5.44 monthly for a monitoring and prevention program against invasive pests. The aggregate WTP was US $540 million per year. The result shows that respondents were sensitive to the program's scope; this was revealed in the high rate of participation in the survey and an excellent WTP for the prevention of forest pest invasion than the control.

Research Objective

The main aim of this research is to inform the grassland management decision-making process in B.C. This research examines peoples' willingness to pay in B.C. communities to manage non-native invasive plant species in B.C.'s grasslands.

More specifically, this study explores three main research questions:

1. What are peoples' attitudes and perceptions of the problem of invasive plant species on grasslands in B.C.?
2. How much are people willing to pay per unit, or accept as monetary compensation, for the various attributes such as location, type of control, and degree of control of the control policies for invasive plant species on B.C.'s grasslands in terms of extra taxes?
3. How much are people willing to pay for different packages to control invasive plant species?

This research uses the stated preference method, choice experiment, to answer these questions. Stated preference methods are considered viable tools for exploring social preferences and gauging public support with respect to invasive plant species management (García - Llorente et al., 2011).

Significance of the study

This study provides a basis for an enabling policy and institutional environment that provides a coherent framework for the sustainable prevention and management of non-native invasive plants in B.C. It is hoped that this type of analysis will inform conservation policy in B.C. and other places invaded by non-native invasive plants by determining the willingness to pay for control by landowners, industries, and government ministries to conserve biodiversity.

The next chapter attempts to answer the above research question by describing the methodology, followed by results and discussion.

The final chapter outlines how the result presented in the previous chapter connects to the overall evaluation of grassland invasive species control and management policy options in B.C.

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CHAPTER 2: INVASIVE PLANT SPECIES ON BRITISH COLUMBIA'S GRASSLANDS: ESTIMATING THE BENEFITS OF CONTROL POLICIES

Introduction

Invasive plants are non-native or alien species that, upon introduction to an ecosystem, cause or have the potential to cause economic or environmental harm, including harm to human and animal health (Convention on Biological Diversity, 2002). Invasive plants can destabilize ecosystems, increase the risk of species extinction, and cause significant economic damage (Gurevitch & Padilla, 2004). Invasive plants are among the most important drivers of biodiversity loss and changes in ecosystem services worldwide. The invasion of exotic species poses a threat to the conservation of grasslands. Their introduction undoubtedly creates a shift in the supply of ecosystem services due to the modification of the structures and functions of the recipient grassland ecosystems (Wilcove et al., 1998).

According to Bengtsson (2019) and Hanisch et al. (2020), maintaining grasslands is essential for biodiversity and ecological services. Grasslands offer vital ecosystem services such as carbon sequestration, mitigating climate change, biodiversity, soil conservation, preventing erosion, water filtration and regulation for aquifer recharge and flood control. Other services include pollination, supporting plant reproduction and crop yield, livestock forage for animal feeding, recreational and cultural values, and enhancing human well-being. Various plant species of BC's grasslands, many of which are endangered, make them an important ecosystem at risk from invaders (Grassland Conservation Council of B.C., 2002; Kemp & Michalk, 2007).

According to Gayton (2004), 35% of grasslands are dominated by non-native species, and human activities like farming and urban expansion also have a negative influence (Grassland Conservation Council, 2002). Inadequate information on invasive plants' socio-economic impacts has created a significant barrier to implementing comprehensive national invasive species management programs. It is one of the main reasons for the failure of invasive species issues to feature prominently in the mainstream agenda of most countries (NARO, 2004).

Invasive plants significantly disrupt grassland ecosystems by enhancing carbon sequestration and increasing the rate of nitrogen cycling, with the effects varying depending on the specific ecosystem and climate involved (Liao et al., 2008). However, they also affect the soil's nitrogen and carbon cycles, which can, in turn, impact the hydrological balance due to their greater water consumption compared to native plants, resulting in lower soil moisture (Lovett et al., 2010; Cavaleri & Sack, 2010; Pysek et al., 2012). The alterations introduced by these invasive plants stimulate microbial activities in the soil, consequently leading to heightened nitrogen availability in the invaded soils, strengthening the invasive plants (Castro-Diez et al., 2014; Ehrenfeld et al., 2005; Liao et al., 2008). In addition to these impacts on nutrient cycles, introducing invasive plants increases nutrient concentrations in both ground and surface waters, promoting nutrient leaching (Chamier et al., 2012; Nagler et al., 2008; Ehrenfeld et al., 2003).

From a socio-economic perspective, the impacts of invasive plant species are vast and multifaceted, influencing property values, agricultural productivity, public utilities, tourism, and outdoor recreation (Perrings et al., 2002; Baskin, 2002; Pimentel et al., 2001; Shackleton et al., 2019). Simultaneously, these invasive species trigger a significant loss in biodiversity and alter climate factors, which can pose severe public health risks (Jones, 2019; Rai, 2015). The control of invasive species is an increasingly important issue in society due to its detrimental impacts on ecosystems, economies, and human well-being. However, controlling invasive species often incurs high costs and can face social opposition (Martin et al., 2006; Sheremet et al., 2017). Evaluating the benefits of controlling invasive species requires a comprehensive understanding of the costs involved, the damages avoided, and the potential positive values that can be derived from the presence of these species (Donlan et al., 2015; Roberts et al., 2018). Studies measuring the benefits and costs of controlling invasive species are vital in developing effective management strategies and policies that can address the complex problem of invasive species (Hanley & Roberts, 2018; Diagne et al., 2020; Bradshaw et al., 2016).

This study examines peoples' attitudes and perceptions of the problem of invasive plant species on grasslands in B.C. using a choice experiment. The research explores how much people would benefit (i.e., are willing to pay) from different levels and methods of invasive species control in B.C.'s grasslands. It also determines how much people are willing to pay for different control policy packages. This study bridges the mismatch gap between public preferences and experts' opinions regarding priorities in invasive species control programs and provides a coherent framework for the sustainable prevention and management of non-native invasive plants in B.C. The next section describes the methodology, followed by results, a general discussion, and concluding remarks.

Methodology

Materials and methods

Study Area

The study area is the grasslands in the interior of B.C., the most western province in Canada. The Pacific Ocean borders it on the west, the Rocky Mountains and Alberta border on the east. B.C. borders the United States to the south and Yukon to the north. Landscapes in B.C. include rocky coastlines, sandy beaches, forests, lakes, mountains, inland deserts, and grassy plains. About 14 percent of the B.C. province comprises parks, conservation areas, ecological reserves, and recreation areas. Grasslands cover less than one percent of the province and are mostly to the east of the forested Coast and Cascade Mountains (Grassland Conservation Council, 2002).

B.C.'s grasslands can be found in the following regions of the province:

- East Kootenay Trench
- Okanagan
- Thompson-Pavilion
- Southern Thompson Upland
- Cariboo-Chilcotin and Central Interior
- Sub-Boreal Interior and Northern Boreal Mountains
- Boreal and Taiga Plains
- Georgia Depression

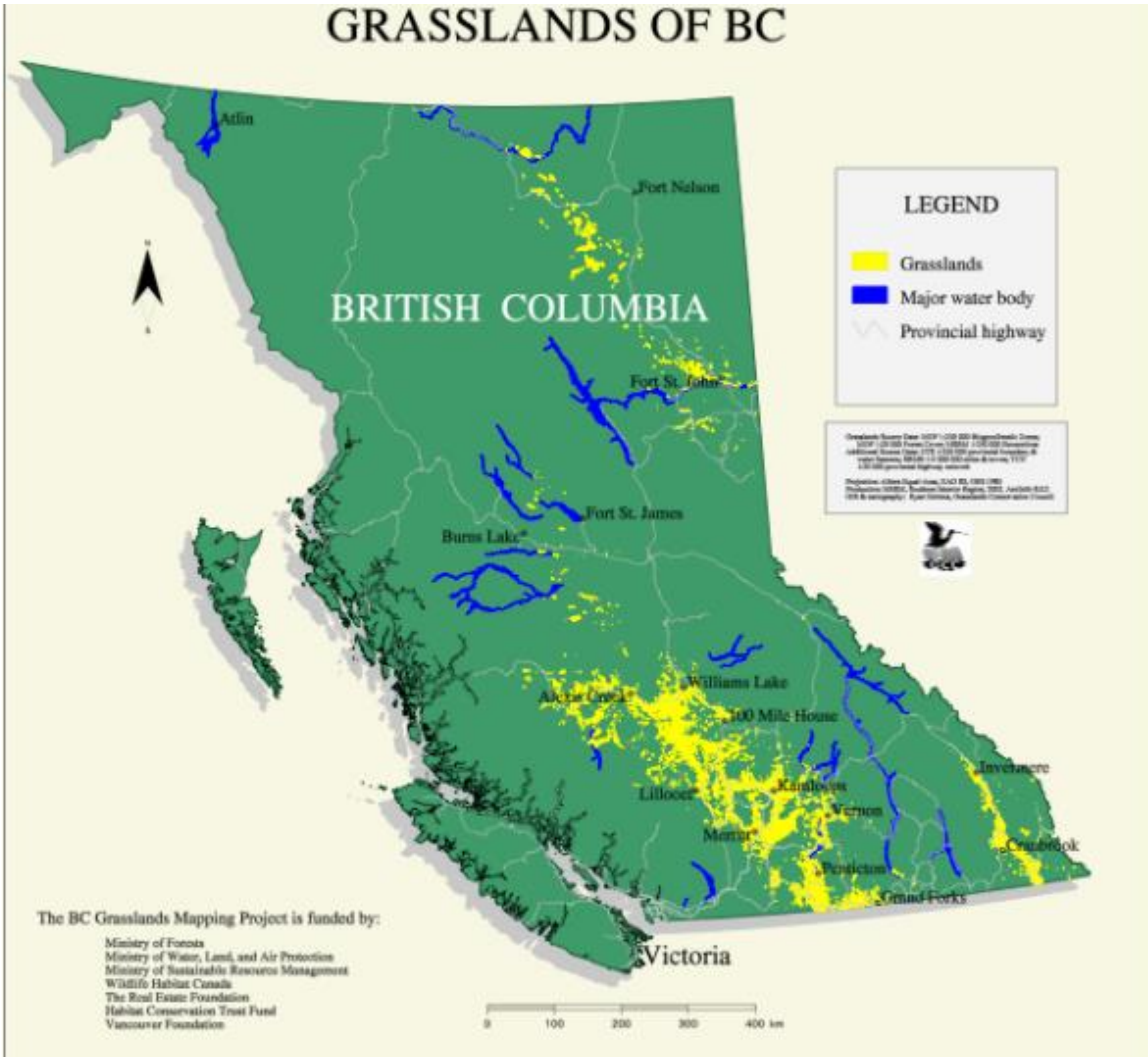

Figure 2.1: Map of B.C. with distribution of grasslands.(Grassland Conservation Council 2009)

Human Ethics Committee Approval

Approval was obtained from the Thompson Rivers University (TRU) Research Ethics Board before contacting potential survey respondents (certificate of approval number 103138 issued on 21st July 2022). Survey distribution and data handling were managed in a fashion approved by TRU's Research Ethics Board.

Experimental Design

This sub-section outlines the step-by-step development and implementation of the choice experiment survey.

First, attributes related to invasive species control policy design were selected guided by Sheremet et al. (2017), and in consultation with academic experts (Nick Hanley, John Janmaat, and Michael Springborn). The survey consisted of four attributes: (1) location of control with four levels (i) everywhere in the interior of B.C., (ii) northern interior B.C., (iii) central interior B.C., and (iv) southern interior B.C.; (2) type of control measures included (i) chemical spraying, (ii) biological control, and (iii) targeted grazing; (3) degree of control had three levels (i) minor, (ii) moderate, and (iii) major; and (4) the additional tax costs per household were (i) $25, (ii) $50, (iii) $75 and (iv) $100 per year (Table 2.1).

Table 2.1: Attributes of the policy options.

Attributes	Levels
Location of control	Everywhere in the interior of B.C. Northern interior of B.C. Southern interior of B.C. Central interior of B.C.
Control measures	Chemical spraying Biological control Targeted grazing
Degree of control	Minor eradication Moderate eradication Major eradication
Additional tax costs for households (per year)	$25, $50, $75, $100.

The next step was to reduce the combinations of alternative choice cards to manageable levels using the Ngene software. The software generates experimental designs that are statistically efficient and unbiased, helping to reduce the number of profiles that need to be presented to respondents. The Ngene software uses the D-error minimizing method to yield an efficient design with five choice cards in eight blocks resulting in 40 choice cards in total. The D-error is the determinant of the variance-covariance matrix of the estimated MNL model using simulated choices. A design with a sufficiently low D-error compared to others is D-efficient. (Sheremet et al.,2017).

The survey was constructed after the efficient design of the five choice cards in eight blocks using the Ngene software. The main survey consisted of four parts. In the first part, the respondents were asked about their general knowledge of invasive plants in B.C.'s grasslands. Included in the first part was a short introduction with a consent statement after mentioning risks and privacy concerns. This was followed by background information on the invasive plant species issue and a map of the study area. It also asked about prior awareness, concerns about the invasion, expectations of future spread without policy, and effectiveness of current policies to deal with the invasion. The second part provided detailed information about the attributes and their levels and an example to help the respondents understand the choice cards and selection. Invasive plant control methods listed in the survey include (Fig 2.2):

- Chemical control method: This involves using pesticides, herbicides, fungicides, and insecticides to destroy undesired invasive plants.
- Biological control method: This involves using natural enemies to reduce the vigour or reproductive potential of invasive plants, e.g., herbivores, plant-attacking insects, mites, and pathogens.

- Targeted grazing method: This involves using livestock for grazing on invasive plants for control purposes, e.g., goats, cattle, and sheep.

Chemical spraying | Biological control | Targeted grazing

Figure 2.2: Images showing various invasive plant control methods.

Location of control: Where the non-native invasive plants would be controlled in B.C.

In addition to everywhere in B.C, the following subareas were included (Figure 2.3):

- Northern interior of B.C. (Sub-Boreal Interior and Northern Boreal Mountains, Boreal and Taiga Plains)
- Central interior of B.C. (Cariboo-Chilcotin and Central Interior)
- Southern interior of B.C. (Southern interior and Southern interior mountains)
- Everywhere in the interior of B.C.

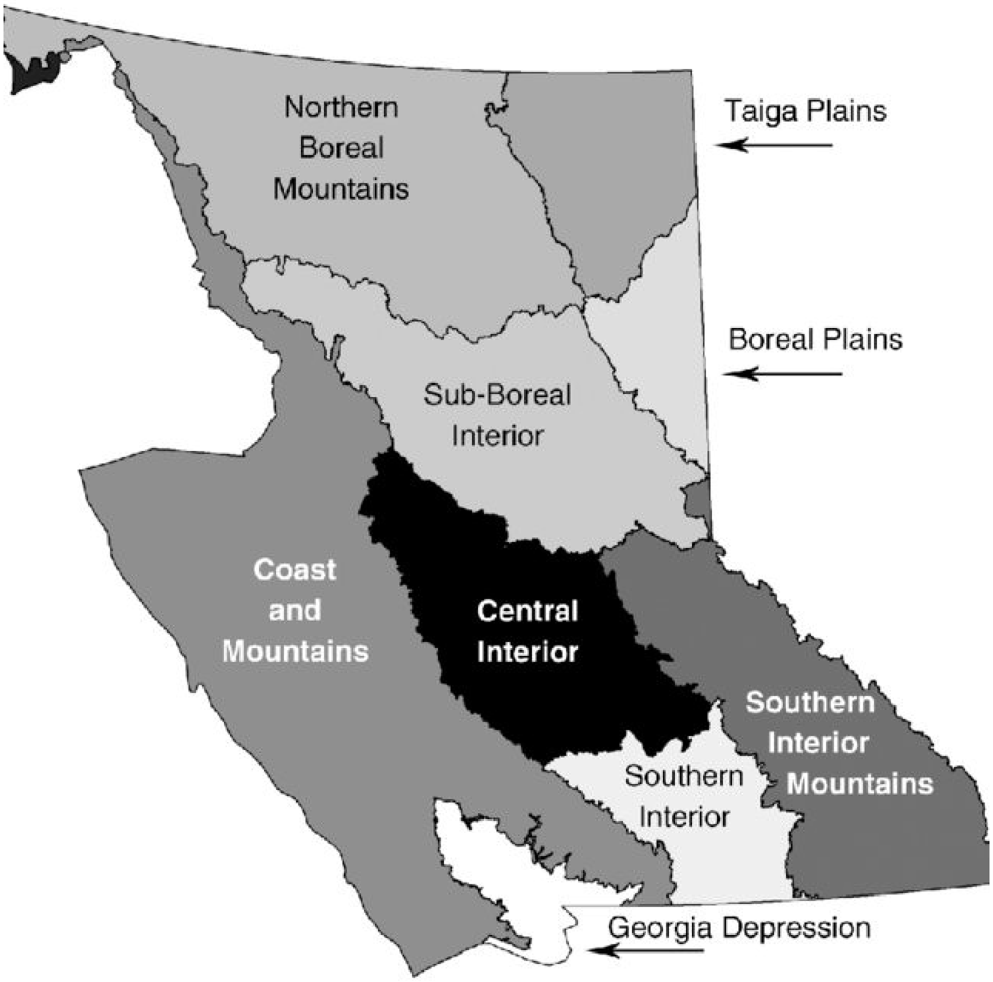

Figure 2.3: Eco-province classification; https://apps.gov.bc.ca/pub/

Each option referred to a given invasive plant control program over a 10-year period. The choice selection consisted of five choice cards with two options describing alternative measures comprising possible invasive plants control policy options and an opt-out option representing a status quo choice of no additional action as per the Ngene software procedure described above. The third part is a section for respondents to reflect on their decision and provide a ranking of the importance of the attributes. The fourth part of the survey asked about respondents' socio-demographic characteristics, e.g., gender, age, household size, education, occupation, income, etc. (See Appendix A for a copy of the survey).

Each respondent received one of the blocks by randomization in the survey. Each choice card contained two control policies and an opt-out option (i.e., none of the two controls), as discussed previously. The following example illustrates a choice card which was also included in the survey as an example to illustrate to respondents how to make choices:

Control policy 1 - Offers a control option for invasive plants with the location of control in the interior of B.C. The invasive control option is chemical spraying for all the grasslands. The degree of control is moderate. Financing such a control option requires a tax increase of $100 annually per household.

Control policy 2 - The location of the control of non-native invasive plant species is in the southern interior only. Targeted grazing will be used to combat this invasion, the degree of control is major, and this option will cost $50 in extra taxes per household annually.

Do nothing option - The 'do nothing' option means you are unsatisfied with the choices offered. You may prefer that the government takes no extra action. It also means that there will be no extra taxes.

Table 2.2: Sample choice card

Attributes	Control policy 1	Control policy 2	Opt-out option
Additional tax per year for control	$100	$50	I prefer that the government takes NO action. NO additional TAXES
Location of control	Everywhere in the interior of B.C.	Southern interior of B.C.	
Control measure	Chemical spraying	Targeted grazing	
Degree of control	Moderate eradication	Major eradication	

Before the launch of the survey to the public and stakeholders, the survey was tested with a pilot from 80 respondents composed of a group of faculty and students at TRU. The aim was to cover a range of views and provide some baseline information on the estimated coefficients, including those in favour and against invasive species control, both experts and non-experts. The final survey was re-designed based on feedback from the pilot test.

Theory and Econometric Methods

In this section, we introduce the theory behind the choice experiment method and connect that theoretical foundation to a functional form to analyse the data using econometrics. Specifically, we will introduce the multinomial logit model (MNL) to analyse the survey data.

The choice experiment methods were based on Lancaster's characteristics theory of value (Lancaster, 1966; Hanley et al.,1998). This model assumes that respondents have selected those alternatives with the highest level of utility among all alternatives. Explicitly, if household i chooses choice g out of j =1, . . . , J alternatives it must be the case that:

$$U_{i,g} \geq U_{i,j} \;\; \forall \;\; i, j \neq g \tag{1}$$

where U is the utility associated with the choice. More specifically, utility is assumed to be comprised of a deterministic component, V and a random (stochastic) component, $\varepsilon_{i,g}$:

$$V_{i,g} + \varepsilon_{i,g} \geq V_{i,j} \; + \; \varepsilon_{i,j} \; \forall \; j \; \neq g \tag{2}$$

Next, it is further assumed that the deterministic portion of total utility depends linearly on attributes that determine the discrete choice of the household:

$$U_{i,j} = V_{i,j} + \varepsilon_{i,j} = ASC_i + \sum \beta_k X_{i,k} + \varepsilon_{i,j}$$

(3)

where $X_{i,k}$ is a vector of attributes from the choice set that determine the discrete choice of respondent i, β_k measures the respondent's additional utility from an additional unit of a covariate to be estimated, and $\varepsilon_{i,j}$ is an error term. The ASC_i is called the alternative specific constant which is assumed to capture unobserved factors explaining the respondent's choice. There can be J-1 alternative specific constants in an MNL model where J is the total number of options. In our design, households faced three choices, as discussed previously, and hence two ASC may enter into the estimation as illustrated next (although entering one ASC will not alter the results). The ASCs capture the difference between the alternative policy options and the do nothing/status quo option.

Socioeconomic and attitudinal variables can be included in the model but cannot enter as household variables in the utility function as they do not vary across the alternative choice set. However, they can be included as interaction variables with the alternative specific constant or with one of the attributes in a choice set. Including the socioeconomic and attitudinal variables will change the utility function as follows:

$$U_{i,j} = V_{i,j} + \varepsilon_{i,j} = ASC_i + \sum ASC_i S_{i,h} + \sum \beta_k X_{i,k} + \sum \beta_k S_{i,h} X_{i,k} + \varepsilon_{i,j}$$

(4)

where $S_{i,h}$ captures H socioeconomic and attitudinal variables of household i.

To measure the welfare change in income that would make the household indifferent between the initial situation and the subsequent policy change assuming the right to the current situation (no action), we use the concept of compensating surplus (CS). Measuring the compensating surplus requires the indirect utility functions under the two cases. If the household gets additional utility from an environmental improvement, then the following should be true:

$$V_0(E_0, m) < V_1(E_1, m)$$

(5)

where E_0 can be thought of the current situation of invasion, E_1 is the improved environment as a result of control of the invasive plant species, and m is the income of the household. Note we removed the i subscript to make the exposition simpler. Compensating surplus is then:

$$V_0(E_0, m) = V_1(E_1, m - CS)$$

(6)

and thus, CS would indicate that the household is willing to pay a maximum amount to make them indifferent to the current situation of no action. Boxall et al. (1996) show that the CS can be expressed as follows:

$$CS = \frac{1}{\beta_M}(V_0 - V_1)$$

(7)

where β_M is the marginal utility of income of the household. It is the change in utility from a unit change in income which is positive in income but negative to taxes since they reduce income. It therefore converts the change in utility from $V_0 - V_1$ to monetary dollars. If $V_1 > V_0$ then there is an improvement in the environment and if the policy is financed through higher taxes then β_M would be negative, resulting in CS to be positive indicating the person's maximum amount they are willing to pay and be indifferent with the no action. If $V_1 = V_0$ then CS = 0 and if the household prefers the no action choice, then $V_1 < V_0$ and CS would be negative implying that the household would want to be paid a minimum amount to accept the policy change. Due to the inherent random component of total utility as a result of unobserved utility and implicit assumptions, preferences cannot be predicted, but we can estimate the probability that household i will choose option j in preference to other alternatives:

$$P_{i,j} = Prob(V_{i,j} + \varepsilon_{i,j} \geq V_{i,h} + \varepsilon_{i,h}) \ \forall \ h \ in \ choice \ set \ C, j \neq h.$$

(8)

The probability that household i will select choice j out of the J alternatives is estimated based on all the attributes that determine $V_{i,j}$ using a multinomial logic model. The probability of household i selecting choice j depends on the utility of that option relative to the utility of all other options as follows:

$$P_{i,j} = \frac{e^{V_{i,j}}}{\sum e^{V_{i,h}}}$$

(9)

The model for invasive species control.

There are three utility functions derived from the MNL model. Each option generates a utility as follows. For policy option 1

$$U_1 = V_1 + \varepsilon = \beta_1 Tax + \beta_2 Location + \beta_3 Type + \beta_4 Degree + \varepsilon$$

(10)

for policy option 2

$$U_2 = V_2 + \varepsilon = \beta_1 Tax + \beta_2 Location + \beta_3 Type + \beta_4 Degree + \varepsilon$$

(11)

and for no action.

$$U_0 = V_0 + \varepsilon = ASC_0 + \varepsilon$$

(12)

There is one alternative specific constant for no action. Utility in the model is determined by the levels of the four attributes for the first two utility functions (i.e., the extra tax, the location of control, the type of control and the degree of control). For no action attributes are irrelevant and only the alternative specific constant appears giving the household a certain utility from selecting it. If $ASC_0 < 0$ then policy is preferred to no policy. The model provides an estimate of the parameters which show the marginal impact of a change in the attribute levels to utility and to the probability that one of these options would be selected. The levels of the attributes were constructed as dummy variables except for extra taxes and the following model can be estimated:

$$U_1 = V_1 + \varepsilon = \beta_1 ASC_0 + \beta_2 Tax + \beta_3 North + \beta_4 Central + \beta_5 South + \beta_6 Biol + \beta_7 TG + \beta_8 Mod + \beta_9 Maj + \varepsilon$$

(13)

where North = 1 if control is in northern B.C, otherwise 0, etc, Biol = 1 if biological control otherwise 0, TG = 1 if targeted grazing otherwise 0, Mod = 1 if moderate eradication otherwise zero, and Maj = 1 if major eradication otherwise zero. The base policy case is chemical spraying, minor eradication, and everywhere in the interior of B.C. Another model included socioeconomic and attitudinal variables which will be discussed in the results section. Some of the socioeconomic and attitudinal variables are whether the respondent is concerned about invasive plant species, whether the respondent grew up in a rural area, and respondent income. ASC_0 is a dummy variable that equals one if the opt-out option was selected and is zero otherwise. The coefficient $\beta_2 = -\beta_M$

in the previous discussion is expected to be negative, signifying disutility from higher taxes and representing the marginal utility of money, while the other levels of the attributes may provide utility to the household. Our prior expectations are that the households that prefer policy to no policy would prefer to control invasive species everywhere in the interior of B.C. relative to the North, Central or South holding other attributes constant and thus β_3, β_4 and β_5 would be negative coefficients indicating disutility. We have no prior expectation with respect to comparing North, Central and South the interior coefficients between them. In terms of type of control, we expect targeted grazing and biological control to be preferred because chemical treatment can be perceived by respondents as more toxic to the environment. Hence, we expect β_6, β_7 to be positive indicating additional utility from these two types relative to chemical spraying. Finally, we expect moderate and major eradication to be preferred to minor eradication, but we have no priors between the impact of moderate relative to major eradication.

The marginal willingness to pay (MWTP) for a change in an attribute or the implicit price per unit change, say a change from chemical spraying to targeted grazing may increase the household's utility, and thus can be calculated by holding utility constant at the initial level, with an increase in the tax, which yields an offsetting disutility. It is thus computed as the negative ratio of the coefficient on the attribute, say β_7, over the coefficient on the cost attribute, β_2. In the above example, the MWTP for this policy change of TG going from 0 to 1 is given by:

$$MWTP = \frac{\Delta Tax}{\Delta TG} = -\frac{\beta_7}{\beta_2} \tag{14}$$

In addition, the economic valuation or total willingness to pay (WTP) for a specific policy package would be equivalent to the compensating surplus introduced earlier:

$$CS = \frac{1}{\beta_M}(V_0 - V_1).$$

(15)

The WTP of the package is computed by the utility of the package (V_1) less the utility of the status quo (V_0) over the coefficient on the cost variable. Hence, in addition to the MWTP for a unit change in an attribute, the WTP for a variety of possible policy packages can be evaluated and compared against each other. For example, the policy baseline package of chemical spraying, everywhere in B.C., and minor eradication would be valued as follows. The utility of the policy is $V_1 = 0$, and the utility of the status quo/no action is $V_0 = \beta_1$; hence, the WTP or compensating surplus is

$$CS = \frac{1}{\beta_2}(\beta_1).$$

(16)

And if $\beta_1 < 0$ then CS > 0 indicating that the household is willing to pay for the policy. For example, for the policy package of targeted grazing in the southern interior region with moderate eradication the valuation would be:

$$CS = \frac{1}{\beta_2}(\beta_1 - (\beta_5 + \beta_7 + \beta_8)).$$

(17)

Suppose we find coefficients using the MNL model such that CS = $51.55 per household per year for chemical spraying, everywhere in B.C and minor eradication (i.e., the base case). This indicates that the household will be indifferent between no action and the above policy with a reduction in income of $51.55 per year in extra taxes. Hence, the maximum amount this household is willing to pay for such a policy is $51.55 per year. Any amount less than this would make this household happier as paying $51.55 would bring them to the utility level with no action. This indicates that the household cares about grasslands since it is willing to pay, and this amount measures the benefits of the control policy to this household. If all households in B.C. had the same preferences and since there are 2 million households in B.C., the benefits of this policy to control invasive plant species can be estimated at approximately $100 million per year. This can be contrasted to the cost of the control policy to determine if it will be accepted by the public. If the cost is higher, then it will not pass a cost benefit test, otherwise it will. By estimating the model using the survey data, we can identify which policy options are worth the most to British Columbians.

Multinomial Logit Model (MNL)

The multinomial logit model is used to estimate the model using the survey data. The MNL model was fitted to the survey data with the statistical software package STATA18. The MNL model is a statistical tool used to analyze and predict the choice of one action among several disjointed actions. It is a type of regression analysis that models the probability of choosing one option as a function of a set of independent variables. Multinomial logit models are best suited for nominal categories, i.e., those categories with no natural ordering; when using the multinomial logit, the dependent variable is usually one that is categorial with more than two possible outcomes or options. For example, in our survey of invasive plant species there were two control policies based on attributes and opt out option. The model estimates a set of coefficients for each level of the attributes which is then used to estimate the willingness to pay to have such an attribute into control policies as discussed above. The model presumes that the possibility of choosing each option follows a multinomial probability distribution. The multinomial logit model is frequently used in economics, marketing, health, and political science fields. It is a model well noted for analyzing categorical data having multiple outcomes.

Although the multinomial logit model is a strong tool for predicting and analyzing the choice of one option among several mutually exclusive options, there are some limitations to the model that are beyond the typical problems such as small sample size, overfitting, omission of important variables. The following are some known limitations of the multinomial logit model:

- Linear relationships: It assumes that the choice probabilities are proportional to the exponentials of linear combinations of the attributes of the alternatives. In practice, this may not always be the case as non-linear relationships do exist.
- The MNL model estimates a single set of coefficients that applies to all households. It assumes that the coefficients are fixed and do not vary across households.
- The MNL assumes that all respondents have the same preferences and does not allow for the estimation of household-level heterogeneity in choice behaviour.
- Independence of Irrelevant Alternatives (IIA) Assumption: The model assumes that the probability of selecting each option is independent of the other options. This assumption may not hold in all cases.
- MNL assumes that the error terms in the model are independent and identically distributed (IID) and cannot accommodate other distributional assumptions for the error terms, including normal, logistic, and extreme value distributions.

In all, the multinomial logit model was used for this thesis as it accommodates discrete choices among multiple categories and assumes individuals aim to maximize their utility when making decisions. The model's coefficients provide interpretable measures of attribute impact, aiding policymakers in understanding the relative importance of different attributes. While the model assumes the independence of irrelevant alternatives, it allows for examining attribute preferences and associated trade-offs. Existing methodologies and literature support the use of MNL studies (Sheremet et al., 2017; Kuhfeld, 2001; Hearne & Salinas, 2002). However, alternative models like mixed logit will be considered in this thesis too.

Results

The Survey Instrument

The experiment was conducted with the use of questionnaires, programmed, and administered with the SurveyMonkey. It was an online survey that took place in March 2023. Before the original survey a pre-test was conducted in February 2023, using the TRU faculty, this is done to estimate the time needed to complete the survey and to locate possible issues.

The original survey was done in two phases, first is the public survey, this was conducted using the SurveyMonkey online global panel having people drawn randomly from all regions in B.C., second was the stakeholders survey, this was conducted among stakeholders of the invasive species and grasslands in B.C. they were people belonging to different organizations with interest in invasive plants and grasslands in B.C.

Table 2.3 below indicates the different organizations stakeholders belong to in B.C. and the number of respondents from each organization. The stakeholder survey had 59 respondents in total all belonging to various organizations in B.C. with some belonging to more than one organization. Most of the respondents belonged to the Grasslands Conservation Council of B.C, followed by the Invasive Species Council of B.C., Nature Conservation of Canada, and B.C. Ministry of Forests. This is not a representative sample of the population of B.C. but a good benchmark to make comparisons with the public's views of the issue.

Table 2.3:Stakeholders in B.C. and the percentage of respondents from each organization

Organizations	# of respondents	Percentage
Invasive Species Council of B.C.	17	28.8%
Grasslands Conservation Council of B.C.	23	39.0%
B.C. Cattlemen's Association	3	5.1%
Nature Conservancy of Canada (B.C. Chapter)	13	22.0%
B.C. Agricultural Climate Action Research Network (ACARN)	2	3.4%
B.C. Ministry of Forests	10	16.9%
B.C. Ministry of Environment	1	1.7%
Ecolog-L	2	3.4%
Agriculture and Agri-Foods Canada	1	1.7%
Other (please specify)	24	40.7%

Other organizations stakeholders belong to include the following: Kamloops Naturalist Club, BC Institute of Agrologists, BC Chapter, Society of Range Management, Forest Professional of BC, BC Burrowing Owl conservation society, and Nature Alberta.

The total from the public who attempted the survey was 1,060. Many respondents, 60 in total, dropped out of the survey at different stages and were not used in the analysis resulting in 1000 households. All the dropouts were those that abandoned the survey before or during the invasive plant control quiz. This could indicate that the most frequent reason for non-participation was a lack of interest in the topic or inadequate knowledge about the invasive plants. The demographic characteristics of the sample (n=1000) are summarised in Table 2.4, this was compared to the B.C. population to determine if the sample was representative. Women constituted more than half of the sample (61%) and significantly more than the B.C population. In the public survey, 31.3% of the respondents were between 18 and 34 years, 47.9% were between the ages of 35 and 64, and seniors (65 years plus) constituted about 21%. Relative to the B.C population the sample had a lower representation of the younger group and a higher representation of the middle-aged households. For the stakeholders' survey, 34% of the total respondents were between 18 and 35, 41% were between 35 and 64 years, and the remaining 25% were seniors. For the location of respondents, the Lower Mainland had the highest drawing, with 59% of respondents coming from there, followed by Interior B.C. and Vancouver Island with 21% and 19% respectively, this is in contrast with the stakeholders' data where most respondents were from the interior B.C. with Lower Mainland having the least. The public survey was representative to the B.C. population in terms of location. In the public data, about 37% of the total respondents had either a bachelor's degree or a postgraduate, while a higher percentage of 83% did so in the stakeholder's data. For the B.C. population, 43.7% had a university degree, slightly higher than that of the public sample. The income distribution of the public sample drawing was skewed towards lower income while for the B.C. annual household income, it was skewed towards higher income**.**

Table 2.4: Socioeconomic and demographic characteristics of the respondents.

	Public Survey		Stakeholders Survey		Census
Characteristics	Respondents	Mean	Respondents	Mean	B.C. population
Share of females	996	61.8%	59	57.6%	51.0%
Age (years) group shares					
18-34	997	31.3%	59	33.9%	19.8%
35-64	997	47.9%	59	40.7%	40.5%
65+	997	20.9%	59	25.4%	20.3%
Grew up in rural area	997	48.7%	59	74.6%	N. A
Location of respondents					
Vancouver Island	997	18.8%	59	6.8%	17.0%
Lower Mainland	997	58.6%	59	1.7%	61.2%
Interior B.C.	997	21.4%	59	91.5%	21.3%
University education	997	36.5%	59	83.1%	43.7%
Household Income distribution					
Low income ($1-$49,999)	923	48.6.%	55	12.7%	26.3%
Middle income ($50,000-$99,999)	994	37.7%	55	40.0%	31.9%
High Income (>$100,000)	994	13.7%	55	47.3%	41.8%

Statistics Canada. 2023. (table). *Census Profile*. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released March 29, 2023. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E (accessed May 25, 2023).

Choice selection analysis

Analysis of the responses to the choice experiment showed a balance in the choice of policy alternatives, with both alternative 1 and alternative 2 being selected in 40% of choice situations. The opt-out status quo option was selected in 20% of cases. Since 11.4 % of respondents chose the opt-out option in all five cards, we infer that the majority, 57.2%, of the total number of opt-out choices were submitted by those respondents. (Table 2.5).

Table 2.5: Choice selected by respondents from the public.

Selections from the 1000 respondents	Number	Percent
Selection of policy 1 of choice situations	1,990	40.0%
Selection of policy 2 of choice situations	1,979	39.8%
Selection of opting out of choice situations	997	20.1%
Respondents selecting opt-out in all 5 cards from 1000 respondents	114	11.4%
Respondents that selected at least one control policy	886	88.6%
Selection of opting out from the 61 who selected the opt-out in all five cards	570	57.2%

Notes: 4,966 represents choice selection from the 1000 respondents. Removing those options that were not selected in each card of three choices yields 4,966 from a total of 14,955.

Respondents opting out from all assigned cards were driven by various reasons. Over 48% believed that the issue of invasive plants should be managed and financed by the private sector rather than the government, while 14% considered the issue insignificant. In comparison, 26% did not believe that the invasive plants control measures included in the policy options of the choice experiment would be effective. Another 13.2% thought the essential aspects of the case were misrepresented, while others protested that taxes in B.C. are already too high, so the control of invasive plants should not be financed through public taxes. While about 4% believed that there were more pressing issues in the province that government should focus on. Issues like homelessness, inflation, housing, and security were among the listed. (Table 2.6)

Table 2.6: Reasons for opting out for all 5 choice cards.

I believe the private sector can control the problem of invasive plants better than the government	34	29.8%
Invasive plants management should be financed exclusively by the private sector	21	18.4%
The issue of invasive plants control is not important or interesting to me	16	14.0%
I do not believe that the proposed control measure will be effective	30	26.3%
Most important aspects of the issue are missing or are misrepresented	13	13.2%
Protest: Taxes are too high	15	13.2%
Other issues	4	3.5%

Note: Reasons for opting out more than 100% due to respondents selecting more than one reason.

When considering responses from the stakeholder survey, we discovered that over 98% chose either choice policy 1 or 2, while just about 2% chose an opt-out option from any of the five cards. Only one respondent opted out of all five cards representing 0.2% of the respondents. As expected, over 98% of the respondents selected at least one control policy since they care about grasslands, and there is a very high interest in invasive plants among this group of respondents. (Table 2.7)

Table 2.7: Choice selected by respondents from the Stakeholders' survey.

Choices selected by 59 respondents	N	Percent
Selection of policy 1 of choice situations	149	16.8%
Selection of policy 2 of choice situations	130	14.7%
Selection of opting out of choice situations	16	1.8%
Respondents selecting opt-out in all 5 cards from 59 respondents	1	0.2%
Respondents that selected at least one control policy	58	98.3%

MNL estimation

The model is estimated with all observations but also for respondents located in Vancouver Island, Lower Mainland, and the Interior B.C. Also, included in this model are socioeconomic and attitudinal variables interacting with the alternative specific constant. The predictors were whether the household was concerned with the problem, grew up in a rural area, was a middle- or high-income earner. In the appendix, the results without the socio-economic variables is presented. The model estimated in the chapter is as follows:

$$U_j = V_j + \varepsilon = \beta_2 Tax + \beta_3 North + \beta_4 Central + \beta_5 South + \beta_6 Biol + \beta_7 TG + \beta_8 Mod + \beta_9 Maj +$$
$$+\beta_1 ASC_0 + \beta_{1,1} ASC_0 RG + \beta_{1,2} ASC_0 UD + \beta_{1,3} ASC_0 MI + \beta_{1,4} ASC_0 HI + \beta_{1,5} ASC_0 CRN + \varepsilon$$

(18)

Where RG is a dummy variable =1 if respondent j spent at least part of their childhood growing up in a rural area, otherwise zero, UDj =1 if respondent j has a university degree, otherwise zero, MI =0 if household's income is in the middle of the distribution, HI if household is in the high income group and CRN is concerned (i.e., 1 not concerned to 5 extremely concerned). All these variables interact with the alternative specific constant. How concerned the respondent is with the invasive species issue interacts only with respect to ASC_0 with a dummy =1 if no action is selected. In a model without the socioeconomic and attitudinal variables we showed in the methods section that policy is preferred to no policy if $\beta_1 < 0$, in this framework the utility a person gets from no action is

$$V_0 = \beta_1 + \beta_{1,1} RG + \beta_{1,2} UD + \beta_{1,3} MI + \beta_{1,4} HI + \beta_{1,5} CRN$$

(19)

Results from MNL estimation

Table 2.8 shows the estimated coefficients from the MNL model including attributes and socioeconomic variables that interact with the alternative specific constant. In the appendix C, we show the results without the socioeconomic and attitudinal variables. The results without the socioeconomic and altitudinal variables are very similar with respect to the attributes and their levels.

For all observations

The t-tests were conducted on each estimated coefficient to determine if it is statistically significantly different than zero. The coefficient β_2=$-\beta_M$ representing the marginal disutility from a unit of higher taxes is negative and significant (p<0.01). Our prior expectations that the households that prefer policy to no policy would also prefer to control invasive plants everywhere in the interior of B.C. relative to regional control is materialized. Hence the estimated coefficients β_3, β_4 and β_5 are negative coefficients indicating disutility directing policy towards regions relative to directing control all over in the interior of B.C. Evidence using the Wald test indicates that the utility of the southern region estimated at -0.655 is undistinguishable with that of the Central region estimated at -0.659 (p=0.947). Also, the northern region is preferred to the central region ($p < 0.001$) and to the south region ($p <0.001$). Hence, overall, the location of control in terms of additional utility is in the following order: Everywhere in B.C., North, and lastly the South and Central regions. In terms of type of control, targeted grazing and biological control are preferred to chemical spraying. The estimated coefficients β_6, β_7 are positive and statistically significant (p<0.001) indicating additional utility from these two types relative to chemical spraying. Evidence using the Wald test indicates that the predicted utility from targeted grazing of 1.27 is preferred to biological control with an impact of 0.851 (p<0.001). Given the sample evidence in terms of control type of policies the ranking is targeted grazing followed by biological control followed by chemical spraying.

Finally, as expected, moderate and major eradication gives more utility to the household than minor but the impact of moderate relative to major eradication is preferred (p = 0.019). Given the sample evidence it seems that moderate is preferred to major and last in terms of preference is minor eradication.

For the general model in this section the estimation for no action depends on the socioeconomic variables as explained previously. The estimated coefficients for no action are all negative and statistically significant except for HI which is not significant. Respondents who grew up in a rural area, have a university degree and have a middle income receive a lower utility from not acting than those who grew up in an urban area, don't have a university degree, and belong to the low or high-income group. Increased concerns reduce utility.

$$\widehat{V_0} = 0.515 - 0.222RG - 0.205UD - 0.148MI + 0.052HI - 0.617CRD < 0$$

Assessing this at the sample means alongside being concerned with the control of invasive plants at its sample mean of 2.90 close to being neutral of 3, yields an estimated value of -1.51. In the case of an extremely concerned at 5 of the Likert scale respondent utility is much higher at -2.80. In the case of someone not concerned = 1 utility is much lower at almost zero -0.33. Comparing these values with the no policy the result of this study shows that base case policy is preferred to no policy given a modest concern.

Regional results: Vancouver Island respondents

Again t-tests were conducted on each estimated coefficient to determine if it is statistically significantly different than zero. The coefficient β_2=$-\beta_M$ representing the marginal disutility from a unit of higher taxes is negative estimated at -0.015 with 95% CI-0.0184, -0.011] and significant (p<0.001). Similar to all observations, households prefer to control invasive plants everywhere in the interior of B.C. relative to regional control is materialized. Hence the estimated coefficients β_3, β_4 and β_5 are negative and statistically significant coefficients. Evidence using the Wald test indicates that Vancouver Islanders prefer controlling the Northern region relative to the South region (p=0.0002) and Central preferred to the South (p=0.0123) but cannot reject the null of no difference in impact on utility between North and Central regions (p=0.189). Hence, overall, the location of control in terms of additional utility is in the following order: Everywhere in the interior of B.C., North and Central, and lastly the South region. In terms of type of control, targeted grazing and biological control are preferred to chemical spraying. The estimated coefficients β_6, β_7 are positive and statistically significant (p<0.001). Evidence using the Wald test indicates that the predicted utility from targeted grazing of 1.51 is preferred to biological control with an impact of 0.948 (p=0.0001). Given the sample evidence in terms of control type of policies the ranking is targeted grazing followed by biological control followed by chemical spraying.

Finally, as expected, moderate and major eradication gives more utility to the household than minor but the impact of moderate relative to major eradication is undistinguishable (p = 0.353).

The estimated coefficients for no action are all negative and statistically significant except for two income levels which are not significant. Similar results are obtained relative to all observations.

$$\widehat{V_0} = 0.962 - 0.444RG - 1.405UD - 0.225MI + 0.326HI - 0.666CRD < 0$$

Regional results: Lower Mainland respondents

The coefficient $\beta_2 = -\beta_M$ is negative estimated at -0.0176 and significant (p<0.0001). Similar to the estimation with all observations, households prefer to control invasive plants everywhere in the interior of B.C. relative to regional control. Evidence using the Wald test indicates that the utility of the southern region is undistinguishable from that of the Central region (p=0.316). Also, the northern region is preferred to the central region (p < 0.001) and to the south region (p <0.001). In terms of type of control, targeted grazing and biological control are preferred to chemical spraying (p<0.001) and targeted to biological (p<0.0001). Finally, as expected, moderate and major eradication gives more utility to the household than minor but the impact of moderate relative to major eradication is undesignable (p = 0.540). The estimation for no action depends on concern as the socioeconomic variables are not significant.

$$\widehat{V_0} = 0.453 - \ 0.153RG + 0.076UD - 0.007MI + 0.150HI - 0.6697CRD < 0$$

Regional results: Interior B.C. respondents

The coefficient β_2=$-\beta_M$ is negative, estimated at -0.0134 and significant (p<0.0001). Similar to the estimation with all observations, households prefer to control invasive plants everywhere in the interior of B.C. relative to regional control. Evidence using the Wald test indicates that the utility of the southern region is undistinguishable from that of the Central region (p=0.645). Also, the northern region is preferred to the central region (p < 0.018) and to the south region (p <0.075). In terms of type of control, targeted grazing and biological control are preferred to chemical spraying (p<0.001) and targeted grazing to biological (p-=0.0001). Finally, as expected, moderate and major eradication gives more utility to the household than minor but the impact of moderate is preferred to major eradication (p = 0.0005). The estimation for no action depends on concern and middle income.

$$\widehat{V_0} = 0.276 - \ 0.115RG - 0.327UD - 0.408MI - 0.215HI - 0.460CRD < 0$$

Stakeholders' survey results

Considering respondents from the various grassland organizations in B.C., an increase in tax will result in marginal disutility. This is because β_2, is -0.015 and significant (p<0.001). In addition, when considering the location of control, the estimated coefficients β_3 and β_4 are negative indicating disutility with respect to North and Central relative to everywhere in the interior of B.C.

The coefficient β_5 is not statistically significant, hence stakeholder respondents may not deduce additional utility from controlling the southern relative to everywhere in the interior of B.C. Control of Southern interior yields more utility than Central interior (p=0.0001) most likely due to most respondents being from the southern interior. In terms of type of control, targeted grazing and biological control are preferred to chemical spraying (p<0.01). The estimated coefficients β_6, β_7 are positive indicating additional utility from these two types relative to chemical spraying. However, biological, and targeted grazing impacts are not statistically significant different (p=0.361). Also, for the stakeholder respondents it is evident that moderate and major eradication gives more utility to the households than minor but the impact of moderate relative to major eradication is indeterminant (p=0.407). Of course, policy is preferred to no policy since the ASC coefficient is -2.858 (p <0.0001).

Table 2.8: MNL Model 2 for valuation of attributes of control policies

	All observations		Vancouver Island		Lower Mainland		Interior B.C.		Stakeholders	
Extra taxes	-0.016	***	-0.015	***	-0.018	***	-0.013	***	-0.015	***
	[-0.018,-0.014]		[-0.018,-0.011]		[-0.020,-0.015]		[-0.017,-0.010]		[-0.022,-0.009]	
Northern interior	-0.368	***	-0.360	***	-0.276	***	-0.637	***	-0.727	***
	[-0.470,-0.266]		[-0.600,-0.120]		[-0.409,-0.144]		[-0.861,-0.413]		[-1.168,-0.286]	
Central interior	-0.659	***	-0.554	***	-0.590	***	-0.965	***	-1.125	***
	[-0.773,-0.545]		[-0.810,-0.297]		[-0.741,-0.439]		[-1.210,-0.720]		[-1.604,-0.646]	
Southern interior	-0.655	***	-0.955	***	-0.501	***	-0.898	***	-0.090	
	[-0.765,-0.544]		[-1.225,-0.684]		[-0.644,-0.358]		[-1.141,-0.654]		[-0.503,0.330]	
Biological control	0.851	***	0.948	***	0.827	***	0.900	***	0.698	***
	[0.753, 0.949]		[0.721, 1.174]		[0.698, 0.956]		[0.686, 1.113]		[0.288,1.109]	
Targeted grazing	1.268	***	1.507	***	1.153	***	1.397	***	0.918	***
	[1.136, 1.400]		[1.190, 1.823]		[0.982, 1.324]		[1.110, 1.684]		[0.402,1.433]	
Moderate eradication	0.541	***	0.333	**	0.584	***	0.676	***	1.330	***
	[0.411, 0.670]		[0.025, 0.641]		[0.416, 0.752]		[0.393, 0.959]		[0.804,1.859]	
Major eradication	0.399	***	0.200		0.536	***	0.212	*	1.126	***
	[0.295, 0.503]		[-0.039, 0.439]		[0.399, 0.673]		[-0.017, 0.441]		[0.684,1.568]	
ASC0: No policy	0.515	***	0.963	***	0.453	***	0.276		-2.858	***
	[0.281, 0.749]		[0.416, 1.509]		[0.137, 0.769]		[-0.255, 0.807]		[-3.362,-2.354]	
ASC0*Concern	-0.617	***	-0.666	***	-0.697	***	-0.456	***		
	[-0.697,-0.538]		[-0.860,-0.471]		[-0.801,-0.592]		[-0.630,-0.282]			
ASC0*Rural Growing	-0.222	***	-0.444	**	-0.153		-0.115			
	[-0.369,-0.075]		[-0.793,-0.095]		[-0.359, 0.052]		[-0.435, 0.206]			
ASC0*University Degree	-0.205	***	-1.405	***	0.076		-0.327	*		
	[-0.359,-0.051]		[-1.907,-0.903]		[-0.120, 0.273]		[-0.686, 0.033]			
ASC0*Middle income	-0.148	*	-0.225		-0.007		-0.408	**		
	[-0.299, 0.003]		[-0.592, 0.141]		[-0.205, 0.191]		[-0.740,-0.076]			
ASC0*High income	0.052		0.326		0.150		-0.215			
	[-0.158, 0.262]		[-0.182, 0.834]		[-0.112, 0.413]		[-0.749, 0.319]			
Number of observations	14,868		2,787		8,697		3,191		885	
χ^2	2637.82	***	487.78	***	1572.61	***	596.07	***	193.12	***

*** p<.01, ** p<.05, * p<.1

Public Support for Invasive Plant Species Control Measures and Programs

Marginal willingness to pay (MWTP) values quantify the monetary worth of an attribute modification. This shows how much a British Columbian would be willing to pay for various invasive plant species control measures or packages. MWTP is the monetary value of switching from baseline attribute levels to an alternative attribute level. It is the marginal utility of the change in attribute level multiplied by the inverse of the marginal utility of income to convert the marginal utility gain or loss to monetary value. The implicit prices are derived as follows:

$$MWTP\ for\ attribute\ modification = -\frac{\beta_i}{\beta_2} \tag{20}$$

where $-\boldsymbol{\beta_2}$ is the marginal utility of income and $\boldsymbol{\beta_i}$ is the change in the attribute level from the baseline case. When the MWTP is negative it shows how much a British Columbian would demand a monetary compensation. Since an attribute level could reduce utility, the household will require an increase in income to be indifferent with the change in the attribute level from baseline. An increase in income can be achieved by accepting monetary compensation, which can be a tax reduction.

Table 2.9 shows the MWTP per unit change per household per year for all observations and the three regions. For all observations, households want to be compensated when location is regional relative to everywhere in the interior of B.C. since the implicit prices are negative and significant. For control in the northern B.C. a household from the public would require compensation of $22 per year while for the southern interior a minimum compensation of $40 would be required and for Central a payment of $41 per year would be needed. The people in the survey want higher compensation for control in the central region and southern relative to northern B.C. For type of control biological control is worth an extra tax of $52 per household per year relative to chemical spraying and $78 per household per year for targeted grazing relative to chemical spraying. As for degree of control people prefer moderate and major to minor and willing to pay up $33 per year per household for moderate and $24 for major relative to minor eradication. For regional areas a similar pattern is observed only the confidence intervals are wider due to the lower number of observations. Respondents place a very high value to targeted grazing relative to biological control in all the regions. The results from the Lower Mainland are closer to the estimation with all observations which is to be expected since 58.6% of the respondents were from Lower Mainland. In all regions, moderate and major eradication is preferred to minor eradication. Similar prices were obtained with the small sample from stakeholders with the only major difference being that they would want a compensation for eradication in the north of $47 per year per household, and for the central $73 relative to everywhere in the interior but for the south the compensation is only $5 and not statistically significant (p=0.695) relative to the interior of B.C. This latter result is not surprising since most of the people surveyed were from the southern region and is different from the public survey with respect to this attribute level. For type of control the targeted grazing is priced at $60 and biological control at $45. Moderate eradication is priced at $87 and major at $73.

Table 2.9: MNL Model 2 Implicit prices of attributes of control policies.

All observations				Vancouver Island			
	WTP per unit change		[95% conf interval]		WTP per unit change		[95% conf interval]
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior	-22	***	(-30, -15)	Northern interior	-24	**	(-43,-5)
Central interior	-41	***	(-49, -32)	Central interior	-37	***	(-59,-16)
Southern interior	-40	***	(-50, -31)	Southern interior	-65	***	(-94, -36)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	52	***	(46,59)	Biological control	64	***	(47,82)
Targeted grazing	78	***	(71,86)	Targeted grazing	103	***	(81,125)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	33	***	(26,40)	Moderate eradication	22	**	(4,41)
Major eradication	24	***	(18,31)	Major eradication	13	*	(-2,29)
Lower Mainland				Interior of B.C.			
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior.	-15	***	(-23,-7)	Northern B.C.	-47	***	(-70,-24)
Central interior	-33	***	(-43, -23)	Central interior	-71	***	(-100,-43)
Southern interior	-28	***	(-38, -18)	Southern interior	-66	***	(-96,-37)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	46	***	(39,53)	Biological control	66	***	(49,84)
Targeted grazing	65	***	(57,73)	Targeted grazing	103	***	(80,127)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	33	***	(25,41)	Moderate eradication	50	***	(33,67)
Major eradication	30	***	(22,38)	Major eradication	15	*	(-1,32)

The next results show the public preferences and willingness to pay for different types of packages which include all attributes in the package in contrast to the previous analysis which assessed prices of attribute levels per unit change holding other attribute level constant. It shows results for the model with socioeconomic variables assessed at their sample means with households that are slightly concerned=2, at the sample mean 2.9 and those that are extremely concerned=5. The assessment is made for all observations and for moderate eradication. For those slightly concerned, the highest valued package is everywhere in B.C. using either biological control priced at $145 with 95% CI [133,157] or targeted grazing at $171 per household per year in extra taxes with a 95% CI [160,183]. Chemical spraying is also valued but significantly lower at $92 per household per year with control location everywhere in B.C. Thus, targeted grazing and biological control are preferred to chemical controls. For those extremely concerned prices ranged from $208 for chemical spraying to $287 for targeted grazing.

Table 2.10: Willingness to pay per year per household for control policies: All observations and moderate eradication.

		Slightly concerned = 2			Concerned = 2.9			Extremely concern = 5		
Location of control	Type of control	WTP		95% CI	WTP		95% CI	WTP		95% CI
Everywhere in interior B.C.	Chemical	92	***	(83,102)	127	***	(115,139)	208	***	(186,230)
	Biological	145	***	(133,157)	180	***	(166,194)	261	***	(236,285)
	Targeted grazing	171	***	(160,183)	206	***	(192,220)	287	***	(262,312)
Northern interior	Chemical	70	***	(60,79)	104	***	(93,115)	185	***	(165,205)
	Biological	123	***	(113,133)	157	***	(145,169)	238	***	(216,260)
	Targeted grazing	149	***	(138,159)	183	***	(171,195)	264	***	(242,286)
Central interior	Chemical	51	***	(43,60)	86	***	(77,95)	167	***	(148,185)
	Biological	104	***	(95,114)	139	***	(129,149)	220	***	(199,240)
	Targeted grazing	130	***	(121,139)	165	***	(155,175)	246	***	(225,266)
Southern interior	Chemical	52	***	(42,61)	86	***	(77,95)	167	***	(149,185)
	Biological	105	***	(95,114)	139	***	(129,150)	220	***	(200,240)
	Targeted grazing	131	***	(121,141)	165	***	(154,176)	246	***	(226,266)

The IIA assumption and problems with testing

When estimating multinomial logit models, researchers frequently attempt to assess a characteristic known as the "Independence of Irrelevant Alternatives" (IIA). According to the IIA assumption of discrete choice theory, when people are given a choice between two options, say policy 1 and opt-out option, they should not be influenced by whether policy 2 is present or not when making their decision (Allison, 2012).

To further illustrate, let p1, p2, and "oo" represent the probability of selecting policy 1, policy 2, and opting out, respectively. The two concurrent binary logit models can be used to represent the multinomial logit model.

$$\ln\left(\frac{p_{i,p1}}{p_{i,oo}}\right) = \beta_1 x_i$$

$$\ln\left(\frac{p_{i,p2}}{p_{i,oo}}\right) = \beta_2 x_i$$

(21)

where x_i represents a column vector of independent variables for individual i, and β_1 and β_2 are row vectors of coefficients. The IIA property states that β_1 remains the same regardless of whether policy 2 is included in the survey, and β_2 remains the same regardless of whether policy 1 is included. To test this assumption, the Hausman-McFadden test (1984) and the Small-Hsiao test (1985) are often used. Both tests follow a similar approach:

1. For each alternative, individuals who chose that alternative are removed from the dataset.
2. The model is re-estimated using the remaining alternatives.
3. A test is constructed by comparing the new estimates obtained from the modified model with the original estimates.

In our survey, we can exclude those that selected policy 2 and estimate a binary logit model to predict policy 1 vs. opt-out. This model's binary coefficients (β_1) can be compared to multinomial coefficients to determine their similarity. We can exclude those that selected policy 1 and estimate the second equation using a binary logit model, comparing its coefficients to the multinomial coefficients. We can also test without the opt-out. We conducted the the Hausman-McFadden test with the following results. When excluding the no action and re-estimating the MNL with only the two control policies the coefficients did not change significantly (p-value 0.97) but when removing policy 2 while keeping policy 1 and no action the coefficients change significantly (p-value < 0.00001) indicating violation of the IIA assumption. When removing policy 1 and keeping policy 2 and no action the IIA assumption is also violated.

However, there are concerns that we want to point out with the testing of the IIA assumption. Allison (2012) states that IIA cannot be tested with the data from the survey due to a number of issues. One of the issues is that the Hausman-McFadden and Small-Hsiao tests perform poorly (Fry and Harris, 1996 and 1998, Cheng and Long, 2007) due to sample size and statistical power to detect a false null hypothesis. Cheng and Long (2007) found restricted choice set tests unsuitable for applied work. Allison (2012) does not advocate using these tests, including the issue of using the same dataset to run binary logit models as if an independent survey containing two choices would yield identical results. We do not know if an independent survey with two choices would yield the same results from a survey with three choices but examining two of these by excluding one choice.

Alternatives to the MNL model include Nested Logit or Mixed Logit which can relax the IIA assumption, but they also have their own set of assumptions and complications. For completeness and to compare and contrast we provide estimates from the mixed logit model in the next section.

The Mixed Logit Model

The mixed logit model, also known as the random parameter logit model, is an advanced econometric model for discrete choice data. The mixed logit model captures unobserved preference heterogeneity by allowing explanatory variable influences, or parameters, to change between individuals, unlike the multinomial logit model. The mixed logit model is a powerful tool for analyzing discrete choice data, offering both strengths and challenges. Advantages include flexibility as it does not assume the IIA assumption, capturing heterogeneity, models correlation across choices and yields a better fit to the data. Disadvantages includes computational difficulties and complexity, identifiability, and potential overfitting.

The mixed logit model with random coefficient for the extra taxes variable was estimated also but the null hypothesis that the coefficient is fixed could not be rejected. The results from the random and fixed coefficients model were almost identical for all observations. For regional regressions the estimations did not converge and all iterations start from a non-concave position with random parameters. The results presented below are estimated using the mixed logit model with fixed parameters as it converged fast. The mixed logit model gives very different results from the MNL estimation because it uses different simulation methodology than the MNL. The MNL model is estimated using the Maximum Likelihood Estimation (MLE) technique while the mixed logic model uses the Hammersley point set for Monte Carlo integration, a quasi-random sequence of draws, to estimate parameters. Even if fixed coefficients (i.e., no random variation) are specified, the numerical integration involved in estimating the mixed logit can introduce differences compared to the maximum likelihood estimation used in MNL.

Results from the Mixed Logit Model

For all observations

Results from the mixed model are different. The coefficient β_2=$-\beta_M$ representing the marginal disutility from a unit of higher taxes is negative but significantly lower 0.006 (i.e. a marginal utility of income of 167) relative to the MNL at 0.016 (a MU of income of 62.5) and is significant ($p<0.01$). Our prior expectations that the households prefer policy, to no policy, would also prefer to control invasive plants everywhere in the interior of B.C. relative to regional control is materialized. The estimated coefficients β_3, β_4 and β_5 are negative and statistically significant coefficients indicating disutility directing policy towards regions relative to directing control all over in the interior of B.C. Evidence using the Wald test indicates that the utility of the southern region, central region and north cannot reject the null hypothesis that they are different. Comparing North and Central region a p-value = 0.141, North and South region a p-value = 0.343, and Central and South region a p-value = 0.623. Hence, everywhere in B.C. is preferred to any regional control. Furthermore, one cannot distinguish if one region is preferred to another in contrast to the MNL model whereby the North was preferred. In terms of type of control, targeted grazing and biological control are preferred to chemical spraying. The estimated coefficients β_6, β_7 are positive and statistically significant ($p<0.001$) indicating additional utility from these two types relative to chemical spraying. Evidence using the Wald test indicates that the predicted utility from targeted grazing of 1.00 is preferred to biological control with an impact of 0.87 ($p<0.03$) which is in accordance to the MNL estimation. Given the sample evidence, in terms of control type, the ranking is: targeted grazing, followed by biological control and then chemical spraying. Finally, as expected, moderate and major eradication gives more utility to the household than minor, and households prefer major to moderate given the p-value of the Wald test to be 0.0001. In conclusion major eradication is preferred to moderate eradication which is the opposite of the MNL whereby moderate relative to major eradication is preferred.

For the general model in this section the estimation for no action depends on the socioeconomic variables as explained previously. The estimated coefficients for no action are all negative and statistically significant except for HI which is not significant. Respondents who grew up in a rural area, have a university degree and have a middle income receive a lower utility from not acting than those who grew up in an urban area, do not have a university degree, and belong to the low or high-income group. Concerns impact the no action negatively. A more concerned attitude lowers utility.

$$\widehat{V_0} = 1.646 - 0.224RG - 0.210UD - 0.162MI + 0.054HI - 0.631CRD < 0$$

Assessing this at the sample means, alongside being concerned with the control of invasive plants at a sample mean of 2.90 close to a neutral of 3, yields an estimated value of -0.42 for no action. In the case of an extremely concerned at 5 of the Likert scale, household utility is much lower at -1.75 for no action. In the case of someone not concerned = 1 utility is much higher at 0.78 with no action. Comparing these values with the no policy the result of this study shows that policy is preferred to no policy.

Regional results.

Regional results: Vancouver Island respondents

The coefficient β_2=$-\beta_M$ representing the marginal disutility from a unit of higher taxes is negative, estimated at -0.004 ($p<0.1$) while the MNL yielded a -0.015 ($p<0.001$). In terms of location, the Northern region (p=0.10) and Central (p=0.862) have negative but not significant coefficients relative to all of interior of B.C., while southern (p=0.056) is significant at the 10% level. Evidence using the Wald test indicates that Vancouver Islanders prefer Central to the other two regions. In terms of type of control, targeted grazing and biological control estimated coefficients β_6, β_7 are positive and statistically significant ($p<0.001$). Evidence using the Wald test indicates that targeted grazing is not statistically significant different from biological control (p=0.0.122). Finally, major eradication is preferred to moderate eradication (p = 0.018).

Regional results: Lower Mainland respondents

The coefficient β_2=$-\beta_M$ is negative estimated at -0.008 and significant ($p<0.0001$). Similar to the estimation with all observations households prefer to control invasive plants everywhere in the interior of B.C. relative to regional control. Evidence using the Wald test indicates that the utility of the three regions are undistinguishable by comparison. In terms of type of control, targeted grazing and biological control are preferred to chemical spraying ($p<0.001$) and targeted is not statistically significantly different from biological (p=0.337). Finally, major eradication is preferred to moderate eradication (p=0 .0006)

Regional results: B.C. Interior respondents

The coefficient β_2=$-\beta_M$ is negative estimated at -0.003 and not significant (p=0.211). Similar to the estimation with all observations, households prefer to control invasive plants everywhere in the interior of B.C. relative to regional control. Evidence using the Wald test indicates that the utility of the three regions are undistinguishable. In terms of type of control, targeted grazing and biological control are not statistically significantly different (p=0.256) but preferred to chemical spraying. Finally, moderate and major eradication are not statistically significantly different (p=0.708) but preferred to minor eradication.

Stakeholders' survey results

Considering respondents for the various grassland organizations in B.C., extra taxes result in a marginal disutility of -0.006 but not significant (p=0.145). In addition, when considering the location of control, the estimated coefficients β_3 and β_4 are negative indicating disutility with respect to North and Central relative to everywhere in the interior of B.C. When considering the location of control, the effects are similar to the MNL results. The estimated coefficients β_3 and β_4 are negative and significant. The coefficient β_5 is not statistically significant. In terms of type of control, targeted grazing and biological control are preferred to chemical spraying. The estimated coefficients β_6, β_7 are positive indicating additional utility from these two types relative to chemical spraying. However, biological, and targeted grazing impacts are not statistically significant different (p=0.203). Also, for the stakeholder respondents it is evident that moderate and major eradication gives more utility to the households than minor but the impact of moderate relative to major eradication is indeterminant (p=0.371). Of course, policy is preferred to no policy since the ASC coefficient is -1.694 (p <0.0001).

Table 2.11: Mixed Model for valuation of attributes of control policies.

	All Observations		Vancouver Island		Lower Mainland		Interior BC		Stakeholders	
Extra taxes	-0.006	***	-0.004	*	-0.008	***	-0.003		-0.006	
	[-0.008,-0.004]		[-0.009, 0.000]		[-0.011,-0.006]		[-0.007, 0.001]		[-0.014, 0.002]	
Northern interior	-0.314	***	-0.248		-0.239	***	-0.594	***	-0.780	***
	[-0.442,-0.185]		[-0.543, 0.048]		[-0.406,-0.072]		[-0.885,-0.304]		[-1.356,-0.204]	
Central interior	-0.213	***	-0.025		-0.168	**	-0.482	***	-0.528	**
	[-0.330,-0.096]		[-0.301, 0.252]		[-0.323,-0.014]		[-0.735,-0.229]		[-1.036,-0.020]	
Southern interior	-0.249	***	-0.329	*	-0.208	**	-0.327	**	-0.018	
	[-0.391,-0.106]		[-0.666, 0.009]		[-0.393,-0.023]		[-0.646,-0.008]		[-0.584, 0.549]	
Biological control	0.866	***	0.999	***	0.767	***	1.096	***	0.787	***
	[0.755, 0.977]		[0.742, 1.255]		[0.624, 0.910]		[0.835, 1.357]		[0.343, 1.232]	
Targeted grazing	1.003	***	1.235	***	0.848	***	1.255	***	0.440	
	[0.865, 1.142]		[0.903, 1.567]		[0.670, 1.026]		[0.938, 1.572]		[-0.089, 0.969]	
Moderate eradication	0.309	***	0.130		0.371	***	0.371	**	1.006	***
	[0.182, 0.436]		[-0.177, 0.438]		[0.208, 0.533]		[0.082, 0.660]		[0.465, 1.547]	
Major eradication	0.575	***	0.524	***	0.672	***	0.426	***	1.256	***
	[0.445, 0.705]		[0.218, 0.830]		[0.502, 0.841]		[0.134, 0.717]		[0.690, 1.822]	
ASC0 : No action	1.646	***	2.300	***	1.436	***	1.731	***	-1.694	***
	[1.346, 1.945]		[1.605, 2.996]		[1.041, 1.831]		[1.036, 2.426]		[-2.514,-0.874]	
ASC0*Concerned	-0.631	***	-0.669	***	-0.703	***	-0.493	***		
	[-0.711,-0.550]		[-0.867,-0.471]		[-0.808,-0.597]		[-0.673,-0.313]			
ASC0*Rural growing	-0.224	***	-0.417	**	-0.175	*	-0.154			
	[-0.373,-0.076]		[-0.772,-0.061]		[-0.383, 0.033]		[-0.478, 0.170]			
ASC0*University degree	-0.210	***	-1.427	***	0.060		-0.293			
	[-0.366,-0.055]		[-1.930,-0.923]		[-0.138, 0.258]		[-0.655, 0.070]			
ASC0*Middle income	-0.162	**	-0.263		0.005		-0.455	***		
	[-0.315,-0.010]		[-0.634, 0.107]		[-0.195, 0.204]		[-0.793,-0.117]			
ASC0*High income	0.054		0.346		0.163		-0.218			
	[-0.156, 0.264]		[-0.160, 0.852]		[-0.100, 0.426]		[-0.748, 0.312]			
Number of observations	14,841		2,776		8,671		3,177		885	
χ^2	1194.10	***	275.45	***	704.05	***	274.06	***	115.04	***

Notes: *** p<.01, ** p<.05, * p<.1, Robust standard errors were used to construct the 95% confidence intervals (CI). The 95% CI are reported below the estimated coefficients. The estimation was done with STATA 18.

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Table 2.9 shows the MWTP per unit change per household per year for all observations and the three regions. For all observations, households want to be compensated when location is regional relative to everywhere in the interior of B.C., since the implicit prices are negative and significant. For control in the northern B.C., a household from the public would require compensation of $49 per year while for the southern interior a minimum compensation of $39 would be required and for Central a payment of $33 per year would be needed. For type of control, biological control is worth an extra tax of $136 per household per year relative to chemical spraying and $157 per household per year for targeted grazing relative to chemical spraying. As for degree of control, people prefer major eradication to moderate eradication then minor eradication and are willing to pay up to $48 per year per household for moderate eradication and $90 for major eradication relative to minor eradication. For regional areas, a similar pattern is observed; only the confidence intervals are wider due to the lower number of observations. Households place a very high value on targeted grazing relative to biological control in all the regions. The results from the Lower Mainland are closer to the estimation with all observations. In all regions major eradication is preferred to minor eradication. However, the results for Interior B.C. are not reliable, as all estimated coefficients are highly insignificant, while for Vancouver Island only two types of controls, biological and targeted, are significant. Comparing these results with the MNL the Northern location is priced higher in the mixed logit model while the other two regions have similar prices. The two types of controls in the mixed logic model have higher prices than the MNL. Contrary to the MNL, the mixed logit model yields higher prices and preference towards major eradication.

Table 2.3: Mixed Logit Model: Implicit prices of attributes of control policies

All observations				Vancouver Island			
	WTP per unit change		[95% conf interval]		WTP per unit change		[95% conf interval]
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior	-49	***	(-25, -73)	Northern interior	-55		(-139,27)
Central interior	-33	***	(-12, -54)	Central interior	-6		(-67,56)
Southern interior	-39	***	(-15, -62)	Southern interior	-74		(-171, -23)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	136	***	(90,182)	Biological control	225	*	(-16,467)
Targeted grazing	157	***	(113,202)	Targeted grazing	278	**	(16,541)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	48	***	(29,68)	Moderate eradication	29		(-34,93)
Major eradication	90	***	(53,127)	Major eradication	118		(-34,270)
Lower Mainland				Interior of B.C.			
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior.	-28	***	(-49,-7)	Northern B.C.	-225		(-586,136)
Central interior	-20	**	(-39, -1)	Central interior	-182		(-483,118)
Southern interior	-24	**	(-46, -3)	Southern interior	-123		(-332,84)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	91	***	(58,125)	Biological control	415		(-256,1087)
Targeted grazing	101	***	(71,131)	Targeted grazing	475		(-246,1196)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	44	***	(25,63)	Moderate eradication	140		(-59,340)
Major eradication	80	***	(45,114)	Major eradication	161		(-130,452)

The next results show results for the model with socioeconomic variables assessed at their sample means with households that are slightly concerned=2, at the sample mean 2.9 and those that are extremely concerned=5. The assessment is made for all observations and for moderate eradication. For those concerned=2.9, the highest valued package is everywhere in B.C. using either biological control priced at $251 or targeted grazing at $273 per household per year in extra taxes. Chemical spraying is also valued but significantly lower at $115 per household per year with control location everywhere in B.C. Thus, targeted grazing and biological control are preferred to chemical control. The mixed logic model yields higher values for packages than the MNL estimation. The corresponding prices of packages are $180 for biological, $206 for targeted and $127 for chemical spraying.

Table 2.12: Mixed logit WTP to pay per year per household for control policies:

		Slightly concerned = 2			Concerned = 2.9			Extremely concern = 5		
Location of control	Type of control	WTP		95% CI	WTP		95% CI	WTP		95% CI
Everywhere in interior B.C.	Chemical	25	*	(-4,56)	115	***	(88,142)	323	***	(240,407)
	Biological	162	***	(127,196)	251	***	(193,309)	460	***	(337,582)
	Targeted grazing	183	***	(153,214)	273	***	(219,327)	481	***	(362,600)
Northern interior	Chemical	23		(-63,16)	65	***	(39,92)	274	***	(201,347)
	Biological	112	***	(86,139)	202	***	(155,248)	410	***	(300,521)
	Targeted grazing	134	***	(110,158)	223	***	(180,266)	432	***	(335,539)
Central interior	Chemical	8		(-43,27)	81	***	(58,104)	290	***	(216,364)
	Biological	128	***	(102,155)	218	***	(170,266)	426	***	(313,539)
	Targeted grazing	150	***	(126,174)	239	***	(195,284)	448	***	(3393,557)
Southern interior	Chemical	13		(-54,19)	76	***	(54,97)	284	***	(209,360)
	Biological	123	***	(91,154)	212	***	(160,264)	421	***	(305,536)
	Targeted grazing	144	***	(114,174)	234	***	(185,283)	442	***	(330,555)

Discussion

Numerous scholarly investigations have been conducted to explore the extent of individuals' willingness to pay to mitigate the presence of invasive species across various contextual settings. Chakir et al. (2016) employed the choice experiments methodology to assess the willingness to pay of the French populace in relation to the conservation of indigenous biodiversity and the mitigation of the adverse effects produced by the invasive Asian ladybird species. The research revealed that individuals showed a willingness to incur costs to safeguard indigenous species, diminish the use of pesticides, and mitigate the negative impacts caused by Asian ladybirds on residential settings.

The study conducted by Sheremet et al. (2017) investigated the public's preferences and willingness to pay for the control of forest diseases in the United Kingdom. The research revealed that disease management initiatives implemented in forests under public ownership and those held by charitable trusts exhibited a higher likelihood of gaining public support. The significance of incorporating public preferences and economic rewards into the management of invasive species has been emphasized by various case studies investigating the willingness to pay for invasive species control. In their study, Adams et al. (2020) employed the choice experiment methodology to ascertain the monetary value that inhabitants of Florida are ready to allocate monthly for the preservation of their urban woods in the face of invading pests. The study participants showed a willingness to contribute an average monthly amount of US $5.44 towards the implementation of a monitoring and prevention initiative targeting invasive pests. The total willingness to pay amounted to $540 million annually. The findings indicate that the participants demonstrated a heightened awareness of the program's extent, as evidenced by their active engagement in the survey and a significantly higher willingness to pay for the avoidance of forest pest invasion compared to the control group. This thesis' approach is similar to the above studies in that a choice experiment is used to measure the value of control measures to combat environmental issues.

This thesis examines British Columbian's preferences and willingness to pay for potential invasive plant control measures and packages. The choice experiment consisted of two control policy options and an opt-out option which proposes for the government to do nothing more. The major result is that the public is concerned and willing to pay for control of invasive plant species in the interior of British Columbia but the willingness to pay depends on the location, type and degree of control. Results from 1,000 respondents across B.C. indicate serious concern. Preference is given to controls everywhere in the interior of B.C. relative to regions, biological and targeting grazing preferred to chemical spraying, and moderate or major eradication relative to minor eradication. When asked to rank the four attributes in terms of importance for their choices, with 1 being the most important and 4 the least important, the public ranked type of control as the most important factor, followed by degree of eradication, then extra taxes and last the location of spread (See Appendix E-Table E.1).

For the stakeholders a one-way Anova analysis and ranking was detected with the most important attribute by far being the degree of eradication, followed by type of control, then by location and last by extra taxes. That taxes are ranked last in importance and degree of eradication first is not surprising for the stakeholders since they are very concerned about the problem. (See Appendix E-Table E.2).

In comparison between the public's response to the ranking relative to the stakeholders ranking of the same attribute, the following results were noticed. First, extra taxes received more importance to the public than to the stakeholders. Second, degree of control received more importance to stakeholders than to the public in ranking for choice selection. The type of control and location of spread had very high p-value to make any meaningful conclusions in terms of differences in their respective ranking. (See Appendix E-Table E.3)

The responses to the choice experiment indicated an equal preference for policy alternatives 1 and 2 (i.e., 88.6% selected at least 1 control policy), with a smaller portion of participants favouring the status quo opt-out option. A fraction of respondents consistently chose the opt-out option across all five cards (i.e., 11.1% or 114 respondents). Those opting out from all cards had diverse motivations: a significant group felt that invasive plant management should be privately funded, while a small fraction considered the issue unimportant. Some participants expressed skepticism about the effectiveness of the invasive plants control measures proposed. A minority believed the case's crucial aspects were misrepresented or argued that taxes in B.C. are already high enough, advocating against public funding for invasive plants control. A very small number felt other provincial issues, like homelessness and security, were more urgent. When examining stakeholder members' responses, a notable majority selected either policy 1 or 2, and very few chose an opt-out option on any of the cards. A negligible number of respondents opted out on all five cards. As expected, nearly all respondents selected at least one control policy, suggesting strong interest in invasive plant management among this group.

To derive an aggregate for the entire B.C., estimate for the public benefit of invasive plant species control packages, based on these results, would be important in order to compare these benefits with the cost of controlling the invasion. For measuring the yearly benefits of the three control policies, we examine a package that controls the invasion everywhere in the interior of B.C. with moderate eradication since these two attributes were ranked the highest amongst both groups. Also growing up in a rural area, having a university degree and for middle income group were kept at the sample means. Finally, there is a need to account for the fact that 114 or 11.4% opted out from all five card choices and hence are not willing to accept any tax increases. There are approximately 2 million households in B.C. (Statistics Canada, 2023) and assuming that 11.4% with 95% CI [9.4,13.4] would be opting out if all 2 million were surveyed and assuming the same proportion would be opting out then 1.77 million households would be willing to accept an increase in extra taxes. The sample is not representative of B.C. population in terms of the high-income group which is under representative. Even though, the estimated coefficient of the high-income group is not statistically significant with this sample, one would expect high income groups to value controls more than the other groups. Hence, this aggregation can represent a minimum valuation of the packages. Also, the high-income variable, as with the other socioeconomic variables, interacts with the no action specific constant term and it does not affect the implicit prices of the attribute levels (See simple model in the appendix). Assuming the sample is representative of the population of B.C., the annual benefits from chemical spraying to British Columbians is approximately $200 million per year (i.e., $115 per household per year times 1.77 million), while for biological control the benefits are $440 million per year. Targeted grazing is valued at $480 million per year ($273 per household per year times 1.77 million).

Limitations

The behavioural models presented in this thesis are based on rational choice theory, which states that individual preferences are revealed by choices made in discrete choice experiments. As a result, these models are constrained by both the discrete choice experimental method and the rational choice theory. Alternative behaviour theories put out opposing arguments, including the notions that people don't always prioritize utility maximization and that respondents' choices may not be indicative of actual choices. According to Simon's bounded rationality theory (1991), numerous circumstances may influence rationality. Response bias (Schwarz, 1999), cognitive errors (Krosnick et al., 2018), and scenarios lacking genuine consequences (Bertrand & Mullainathan, 2001) are all issues with survey methodologies used in discrete choice experiments. While this thesis design is aimed at behavioural realism, acknowledging potential limitations remains vital when interpreting results.

Concluding remarks

This study examines peoples' attitudes and perceptions of the problem of invasive plant species on grasslands in B.C. using a choice experiment. The research explores how much people are willing to pay, or accept as payment (monetary compensation), for various attributes such as location, type of control, and degree of control for invasive plant species on B.C.'s grasslands in terms of extra taxes. It also determines how much people are willing to pay for different packages to control invasive plant species. Results from 1,000 respondents across B.C. indicate serious concerns and a positive willingness to pay to control the problem. Result also indicates that respondents prefer control everywhere in the interior of B.C. relative to sub-regions of the interior, biological and targeting grazing preferred to chemical spraying, and moderate or major relative to minor eradication. Estimates indicate that at the minimum British Columbian's are willing to pay $200 million per year in extra taxes to control invasive plant species in grasslands everywhere in the interior of B.C. with a moderate or major eradication over the next decade using chemical spraying. Using biological or targeted grazing the valuation doubles to $400 million or more per year. The value shows the benefits of controls but not the costs of controlling nor the productivity of the control measures which would be needed to conduct a cost benefit study. The next chapter discusses how a cost benefit assessment can be conducted as well as people's awareness of the invasion, their opinion on monitoring the problem and effectiveness of the public body to control the problem. This study bridges the gap of mismatch between public preferences and the opinion of experts as regards priorities in invasive plants control programs, and provides a coherent framework for the sustainable prevention and management of non-native invasive plants in B.C.

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CHAPTER 3: RESEARCH CONCLUSIONS, MANAGEMENT IMPLICATIONS, AND FUTURE RESEARCH

Grasslands are part of the world's major ecosystems, covering nearly one-third of the Earth's terrestrial surface (Kemp & Michalk, 2007; Tisdale, 1947). Native grasslands cover less than 1% of the total landmass in British Columbia. Grasslands play a crucial role in maintaining the balance of ecosystems, as they are necessary for preserving biodiversity and storing carbon. They support more threatened and endangered plant and animal species than any other habitat type in the province (Grassland Conservation Council of B.C.).

Grasslands are quickly degrading; in recent decades, they have suffered heavily from planting non-native pastures and crops, fire regime changes, and invasive weeds (McCormack, 2019). The ecosystem services provided by grasslands are affected by invasive plant **eradication** species, which possess a competitive edge over native species, alter soil nutrient cycles, and ultimately reduce the overall productivity of these ecosystems. It is estimated that 35% of the remaining grassland ecosystems in British Columbia are dominated by non-native herbaceous vegetation (Gayton, 2004). Preserving grasslands is essential for maintaining species diversity and numerous ecosystem services (Bengtsson, 2019).

The public needs to be incorporated to achieve the goal of invasive plant control and, ultimately, the preservation of grasslands and the ecosystem services they provide. Understanding public perceptions regarding the control of invasive plant species and grassland preservation is crucial for effective policymaking and management. It ensures that regulations are supported by the majority, aiding in targeted awareness campaigns and better resource allocation. By determining public perception, policymakers can anticipate reactions and foster trust, facilitating smoother policy implementations. Recognizing these perceptions also helps counter misinformation and ensures culturally appropriate solutions. Overall, incorporating public perception can lead to more sustainable and community accepted strategies.

With the aid of a survey, this thesis tried to investigate the level of awareness of the B.C. public about the invasive plant problem and the level of concerns of the public about the long-term risk posed by these invasive plants. Also, we tried to investigate the perception of the public about the effectiveness of the B.C. Ministry of Forest in bringing the problem of invasive plants to the awareness of the B.C. public. The results obtained from the public and the stakeholders regarding awareness and perception of the problem of invasive plants, alongside the perceived effectiveness of the B.C. Ministry of Forest by the public, will be discussed in this chapter.

Awareness of invasive plant species among British Columbians

Awareness among the public is essential to regulate and prevent the introduction of invasive plant species. Awareness can help prevent these invasive plants' introduction and curtail their spread. Lack of public awareness, resource constraints, and improper coordination among public administrators significantly contribute to the inadequate management of invasive plants (Andreu, Vilà, & Hulme, 2009). Raising public awareness about invasive plants is vital to successfully managing biodiversity (Fisher & van der Wal, 2007). People need to be able to distinguish between native plants and non-native invasive plant species; this is essential to prevent detrimental effects on wildlife. (Somaweera, Somaweera, & Shine, 2010). This research attempts to determine the level of awareness of the B.C. public about the problem of invasive plant species.

Table 3.1 shows the results from the first question in the survey after respondents read the background information about the problem; in particular, they were asked on a scale from not aware, slightly aware up to extremely aware the following question:

> "Before receiving this survey, how aware were you of the invasive plant species problem on grasslands in the interior of B.C?"

Respondents of various organizations, usually the stakeholders interested in invasive plant species in B.C., were highly aware of the issue, while the public was less aware.

Table 3.1: Awareness of the invasive species problem on grasslands in B.C.

	Public		Stakeholders	
	Proportion	95% CI	Proportion	95% CI
Not aware	45.5%	(42.4,48.6)	0.0%	
Slightly aware	28.4%	(25.9,31.6)	1.7%	(-1.7, 5.1)
Somewhat aware	19.2%	(16.8, 21.6)	10.2%	(2.2, 18.2)
Very aware	5.5%	(4.0,6.9)	35.6%	(22.9, 48.3)
Extremely aware	1.0%	(0.004, 1.6)	52.5%	(39.3, 65.8)

Notes: The sample size for the public survey was 1000, while that of the stakeholders' survey was 59.

For the public survey, out of the 1000 respondents, 45.5% are unaware of the invasive plant problem in B.C.'s grasslands, 28.4% are just slightly aware, and 19.2% are somewhat familiar. About 5.5 % of the respondents are very aware of the problem, while a small percentage, 1% are extremely aware of the problem. The above figures are in sharp contrast to the stakeholders' survey, in which more than half of the respondents are extremely aware of the problem of invasive plants in B.C., and none are unaware. This is unsurprising because the stakeholders self-selected to complete a survey on invasive plants on grasslands, probably due to their extensive knowledge about the topic since they are usually at the forefront of the campaign against introducing and spreading invasive plants. Another reason for the contrast is that most of the respondents to the public survey might not live near B.C.'s grasslands therefore might have a lot less knowledge about grasslands and the invasive plants disturbing them.

Table 3.2: Level of awareness of the problem of invasive plant species on grasslands across regions in B.C.

Awareness level	Vancouver Island	Lower Mainland	Interior B.C.
Not aware	41.7%	50.3%	37.0%
Slightly aware	33.1%	28.1%	24.9%
Somewhat aware	18.8%	17.8%	24.9%
Very aware	5.4%	3.2%	11.3%
Extremely aware	1.0%	0.5%	1.9%
Respondents	2,804	8,760	3,194

Using the public survey, Table 3.2 illustrate the level of awareness of respondents in B.C. across various regions. Out of the 2,800 plus households surveyed from Vancouver Island, only an insignificant 6.4% were very and extremely aware of the problem of invasive plants on B.C.'s grasslands, lower mainland residents were the least aware of the problem at 3.7% (very and extremely aware), whereas for the Interior B.C. 13.2% were very or extremely aware. This pattern is also reflected at the lower end of the distribution whereby Lower Mainland has the highest percentage of respondents that are not aware of the problem of invasive plant species on grassland, followed by Vancouver Island and finally the Interior B.C. have the lowest percentage of not being aware of the problem.

Table 3.3 shows the results from the second question in the survey; in particular, they were asked the following question:

> "Before receiving the survey, which non-native invasive plant have you heard about?"

Table 3.3: Knowledge of invasive plant species

Type of invasive plant	Public	Stakeholders
Blueweed	14.9%	62.7%
Common tansy	12.7%	86.4%
Dalmatian toadflax	4.0%	91.5%
Hoary alyssum	5.9%	74.6%
Hounds-tonque	4.4%	86.4%
Orange Hawkweed	9.4%	84.7%
Oxeye daisy	11.4%	83.1%
Rush skeletonweed	4.3%	55.9%
Spotted knapweed	15.1%	100.0%
Sulfur cinquefoil	5.5%	89.8%
None of the above	55.0%	0.0%
Others	1.9%	44.1%

Notes: Other invasive plants mentioned by respondents include Japanese knotweed, giant hogweed, cheatgrass, purple loosestrife, silverleaf nightshade, and leafy spurge. Appendix B highlights the different invasive plants in BC, their scientific names, and a brief description.

Table 3. 3 highlights the different types of invasive plants in B.C. known to the respondents. It is observed that more than half of the entire respondents in the public survey are not conversant with any invasive plants, with just a little above 15% being familiar with the Spotted knapweed; this is followed by the Blue weed and Common tansy, which have 14.9% and 12.7% respectively. The least known invasive is the Dalmatian toadflax, with only 4 % of the respondents aware of it. The survey from the organization members shows a sharp contrast from the above, as the entire respondents are aware of the Spotted knapweed. Dalmatian toadflax ranks second with a figure of about 91%, followed by Sulphur cinquefoil, common tansy, and Hounds tonque, each having 89.8% and 86.4%, respectively. It is worthy of note that just about 2% of the respondents in the public survey are aware of other invasive plants other than those mentioned in the survey; this falls

short of the amount for the organization respondents, where well over 44% are aware of a lot more invasive plant.

Perceptions of effectiveness of the B.C. Ministry

The thesis also tried to find out people's opinions about the effectiveness of the B.C. Ministry of Forests in bringing the problem of invasive plants to the awareness of the B.C. public. Approximately 16% of the 853 respondents answered the question.

> How effective is the B.C. Ministry of Forests (responsible for the stewardship of Crown land) in making the public aware of the problem of invasive plant species and why it is occurring?

were "Not sure" indicating a lack of certainty about the effort of the Ministry, suggesting that a lot still needs to be done by the Ministry to make people aware of invasives in B.C.'s grasslands. Also, 14% of 868 respondents do not believe the Ministry is doing anything to motivate the public to do their part in preventing the spread of invasive plants. Out of the 758 respondents that answered the above question, about 29% are yet to learn of any effort put in place by the Ministry to combat invasive plant invasion on grasslands.

Lastly, almost 34% of the respondents are not aware of the actions of non-governmental stakeholders to prevent the further spread of invasive plant species (Table 3.4).

Table 3.4: Effectiveness from the public's perspective

	N	Average	Std error	95% CI	Not sure
How effective is the B.C. Ministry of Forests (responsible for the stewardship of Crown land) in making the public aware of the problem of invasive plant species and why it is occurring?	853	2.54	0.037	(2.47,2.61)	15.9%
How effective is the B.C. Ministry of Forests in motivating the public to do their part to prevent further spread?	868	2.40	0.039	(2.32,2.48)	14.0%

How effective is the B.C. Ministry of Forests in monitoring non-native plant invasion?	758	3.09	0.038	(3.01,3.16)	29.1%
How effective are non-governmental agencies in doing their part to prevent the further spread of invasive plants on grasslands?	730	2.91	0.043	(2.82,2.99)	33.6%

Notes: N represents the total number of people that answered the question, while "Not sure" is a percentage of the total respondents. Likert scale of 1 to 6 was used, ranging from 1 "Strongly ineffective" to 5 "Strongly effective" and 6 "Not sure."

In contrast to the finding from the public survey, only one of the stakeholder respondents is not sure of the effort of the B.C. Ministry of Forest to make the public aware of the problem and motivate them to do their part in preventing the further spread of the invasive plants. However, a more significant percentage of the respondents (23.7%) do not know about the effort of the Ministry of Forest in monitoring plant invasions in B.C. Lastly, only two of the respondents reported being not sure of the effectiveness of non-governmental agencies' actions to prevent the further spread of invasive plants on grasslands (Table 3.5).

Table 3.5: Effectiveness from the stakeholders' perspective.

	N	Average	Std error	95% CI	Not sure
How effective is the B.C. Ministry of Forests (responsible for the stewardship of Crown land) in making the public aware of the problem of invasive plant species and why it is occurring?	58	2.362	0.149	(2.064,2.660)	1.7%
How effective is the B.C. Ministry of Forests in motivating the public to do their part to prevent further spread?	58	1.948	0.116	(1.715,2.181)	1.7%
How effective is the B.C. Ministry of Forests in monitoring non-native plant invasion?	45	2.711	0.176	(2.359,3.063)	23.7%
How effective are non-governmental agencies in doing their part to prevent the further spread of invasive plants on grasslands?	57	3.649	0.134	(3.382,3.916)	3.4%

One of the objectives of the study is to assess people's concern with the invasive plant species problem in order to determine the priority of potential policy and control measures to implement. To this extent, we asked people to reveal how concerned they are about the long-term risk of invasive plant species on B.C.'s grasslands. They were asked on a scale from 1-not concerned, 2-

slightly concerned, 3-somewhat concerned, 4-very concerned to 5-extremely concerned. Table 3.6 shows the results.

Results from the public survey showed on average; respondents are somewhat concerned about invasive plants on grasslands; this is lower when compared to the stakeholders' survey, which is very concerned. The public and stakeholder surveys displayed a similar pattern concerning the future long-term risk of the spread, damage, and effectiveness of controls used to manage invasive species on these grasslands. In summary, respondents from the stakeholder survey are significantly more concerned than the public. This is not unexpected given the interest of the stakeholders on preserving grasslands and that many of the public respondents do not live near grasslands. However, the public is somewhat concerned and prefers action to no action, as shown in the previous chapter.

Table 3.6: Concern of respondents about the long-term risk of invasive species

		Public Survey		Stakeholder Survey	
	Respondents	Mean	95% CI	Mean	95% CI
How concerned are you about non-native invasive plants on grasslands in the interior of B.C.?	999	2.902	(2.838,2.966)	4.169	(3.962,4.377)
How concerned are you about the future long-term risk of the spread of invasive species?	998	3.156	(3.091,3.221)	4.407	(4.237,4.577)
How concerned are you about the future long-term risk of damage to the grasslands by invasive species?	998	3.365	(3.299,3.430)	4.407	(4.237,4.577)
How concerned are you about control not being effective in controlling the spread of invasive species?	997	3.281	(3.215,3.347)	4.203	(3.992,4.415)

We also asked the survey respondents to predict the spread of the invasion if there is no management/policy to contain the invasion over the next decade. Table 3.7 shows the results. Responding to this question, an average of 12.6% of the public data respondents believed that the current 35% invasion would be maintained. In comparison, just 3.4% believe so from the stakeholders' survey. Most of the respondents from both the public data and the stakeholders' data, 35.1 and 33.9%, respectively, believed the level of invasion would increase to about 40 to 60% if no management/policy were implemented to contain them. An average of 20% of respondents from the stakeholder survey believed that over 80 % of the grasslands would be affected over the next ten years; this is higher than the average of 10.4% from the public survey. An average of 20% of the public and stakeholder surveys indicated that they do not know the percentage increase in invasive plant invasion that should be expected in the next ten years.

Table 3.7: Percentage of the grasslands that will be invaded over the next decade if there is no management/policy to contain the spread.

		Public Data		Stakeholder	
	Respondents	Mean	95% CI	Mean	95% CI
The current approximate 35 % invasion	1,000	12.6%	(10.5,14.7)	3.4%	(0.0,8.2)
About 40 to 60% of the grasslands in B.C.	1,000	35.1%	(32.1,38.1)	33.9%	(21.3,46.4)
About 61 to 80% of the grasslands in B.C.	1,000	21.1%	(18.6,23.6)	22.0%	(11.0,33.0)
Over 80% of the grasslands in B.C.	1,000	10.4%	(8.5,12.3)	20.3%	(9.7,31.0)
Do not Know	1,000	20.7%	(18.2,23.2)	20.3%	(9.7,31.0)

Benefits and costs of invasive species control

In order to conduct a full assessment of a policy package of control measures, one needs to measure not only the benefits from the control policy but also the cost of the control policy (Shackleton et al., 2018). From an economic efficiency perspective, if the benefits from a control policy exceed the costs, then it would be worthwhile to undertake such an action, and no action should be undertaken if the costs are higher than the benefits arising from the control measures. The difference between benefits and costs are the net-benefits of the invasive species control policy.

Since any control policy will provide a stream of benefits and a stream of costs across time, it is appropriate to account for time preference and discount the annual expected net benefits to present values using a social discount rate, r. The present value of expected net benefits occurring in year t can be represented as follows.

$$PV(ENB_t) = E\left[\sum_{t=1}^{N} \frac{B_t - C_t}{(1+r)^t}\right]$$

where E is the expectation operator, Bt is the benefit in year t, and Ct is the costs in year t. The benefits accruing to British Columbian's are measured by the value of damage avoided per year. This is measured as the social benefits of grasslands with controls less the social benefits of grasslands without controls per year. In the previous chapter using the survey, we estimated that British Columbians would be willing to pay for control measures relative to no action a maximum dollar amount per year which reflects the value of benefits of avoided damages from control.

The net benefits of invasive species control are equivalent to the value of damage avoided minus the cost of control, and this cost includes any negative side effects of invasive species control (Tye et al., 2007). The cost of control depends on effectiveness and length of time. Effectiveness depends on the type of control, the size of the invasion, and the amount being controlled (Olson & Roy, 2005). Chemical spraying is known to be very effective and can be one of the most effective ways of managing invasive plants in the short term (Barrons, 1969; George & Brennan, 2002; Quazem, 2011), but it is valued less by the public at CDN$200 million per year and is the most expensive relative to biological and targeted grazing. The larger the invasion and the higher the amount controlled, the higher is the cost of control (Cacho et al, 2004). Also, the longer the length of time to control the invasion, the greater the chance the invasive plants will biologically transition and spread causing future damage. A summary is shown in the middle circle of Figure 3.1.

As control measures reduce the damages over time, the expectation is that the cost of control will fall over time. It is expected that costs of control are high initially while eliminating the established invasion and then falling into the future while targeting new invasions before they are fully established. Whereas the benefits from controlling the invasion remain constant, or increase, e.g., individual willingness to pay will increase as incomes increase and aggregate willingness to pay will increase as population increases.

Of importance is that the control policy cost can be decomposed into monitoring costs and treatment costs. Monitoring costs can be defined as the various costs involved in the surveying and mapping of infested areas, conducting field inspections, and using various remote sensing techniques to detect the presence and track the spread of invasive plant species. On the other hand, treatment costs comprise the various methods employed to manage invasive plant species. This may include physical techniques like manual removal, mowing, cutting, and chemical methods such as herbicide application or even using specific animals to graze on targeted invasive plants. Biological control agents, like insects or pathogens can also be used to reduce the population of these invasive to an economically and ecologically acceptable level.

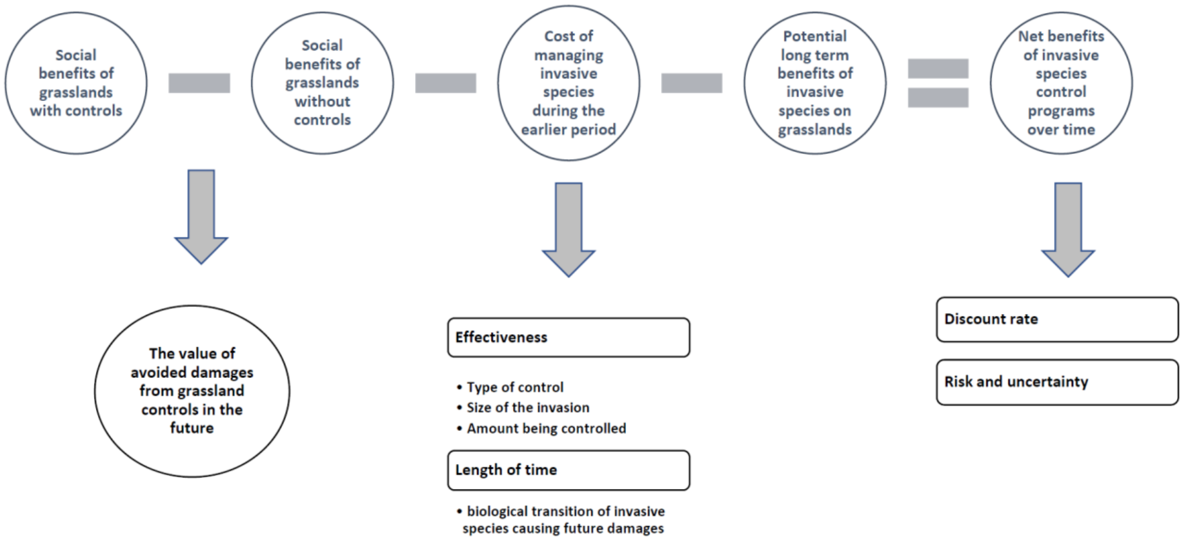

Figure 3.1: Benefits and costs of controlling invasive species.

In addition to subtracting the cost of managing the invasive plant species during the earlier period one needs to subtract any potential long-term benefits of invasive species on grasslands to eventually find the net benefits of the invasive species control program per year. This represents the numerator of the net present value formula above and the circle in the top right of the figure. Finally, because these benefits and costs accrue in the future, a discount rate is required to account for the opportunity cost of not using the funds today in other productive uses. Finally, the future is unknown and thus one has to consider risk and uncertainty which could play a significant role and maybe the precautionary principle can be applied.

Thus, the net benefit of intervention is a complex issue and relies on the effectiveness of control options, the type of control, where and when it is applied, and the risk and uncertainty associated with the future. This thesis explored only one aspect of the problem, and that is peoples' perceptions and willingness to pay to control the invasion. This thesis attempted to determine only the benefits of control as seen from the willingness to pay by the public to control the invasion and not the costs of control. The study found that under moderate eradication, everywhere in the interior of B.C., using chemical spraying, the public is willing to pay $200 million per year at the maximum but is willing to pay double this amount for either biological control or targeted grazing. If controls are effective, then these benefits can continue into the indefinite future. Assuming a social discount rate of 3.5%, which is typically used in cost-benefit studies of public projects in Canada (Boardman et al., 2010) and assuming the valuation of benefits does not increase in the future but remains, say, at $440 million per year, which is a conservative estimated valuation (since high income group was underrepresented in the survey) for biological or targeted grazing, for the indefinite future then the present value of these benefits is estimated at $12.5 billion. If the valuation of these benefits increases at the rate of 2% per year due to the incomes and population of B.C. increasing over time which is reasonable to assume (i.e., a valuation of control elasticity with respect to income of unity) then the appropriate effective discount rate is 1.5% (i.e., 3.5% - 2%) and the present value of benefits of these control policies is estimated at $29.3 billion. Hence, if the cost of controlling invasive species in present value is less than these present value benefits, then controls should be implemented from an economic efficiency perspective.

Management implication and future research

The management of invasive plant species is usually very complex, this is because it involves several stakeholders coming together to make it successful. The success of invasive species management depends on the perception, attitude, and behaviour of the various stakeholders involved (Shackleton et al., 2018; Pysek et al., 2012; Bremner and Park., 2007). Other challenges could be lack of knowledge and awareness, poor cooperation, and ethical concerns among the various stakeholders (Shackleton & Shackleton, 2016; Colton & Alpert, 1998; Shackleton et al., 2016). Most times, stakeholders try to balance economic, social, and environmental factors along with different inherent concerns. In order to make the management of invasive species effective, all these stakeholders must work together to find the best solution. Stakeholders in this context include, but are not limited to public individuals, researchers, government ministries, and non-governmental stakeholders.

This research identified that almost 50% of the public respondents are unaware of the problem of invasive plants in B.C.'s grasslands, and just a minimal 5.5% of the respondents reported being very aware of the problem. Although most of the public live in areas of the province that do not have grasslands, public awareness of the problem in non-grassland areas is still important for monitoring and prevention. People become more vigilant observers because of public awareness of the threats posed by invasive species, enabling for early detection and reporting. This expanded network of monitors significantly enhances the ability to detect new infestations in a timely manner. Rapid response is crucial to minimising invasive species establishment and spread, and enhanced public awareness accelerates intervention efforts. Furthermore, raising public awareness about the ecological destruction caused by invasive species encourages responsible behaviour, such as not planting invasive and refraining from behaviours that spread their seeds. This lifestyle adjustment reduces environmental effect while also preserving biodiversity. Beyond individual actions, public awareness campaigns foster collaboration among a wide range of stakeholders, from government agencies to community organisations, allowing for the formulation of comprehensive policies.

The survey also discovered that the public perceives the Ministry of Forestry not to be effective enough in bringing the problem of invasive plants to the attention of the public. This might be as a result of the Ministry focusing their communication strategy on the actual users of grasslands rather than the general public province wide. This could also be an effective strategy given the spatial population distributions in the province. This inattention might have contributed to the high rate of unawareness among the public. The implication of this is that the Ministry needs to employ various media channels to bring to publicity the existence of these problems. For example, social media is a good platform for propagating news to the public, especially the younger generation, in a fast and efficient manner.

Based on the results of the public survey, the following recommendations can be made; the management of invasive plants should be done in conjunction with the private sector. Although this is already in place, the public needs to be more involved. Better monitoring should be done alongside the public; just like the national parks, migratory bird sanctuaries, national wildlife areas and areas of marine protection all grasslands in B.C. should be protected areas giving the value that people place on them and their perceived environmental benefits.

Future research should investigate the productivity of the three methods of control mentioned in this research vis a vis their cost; this should be used in advising the stakeholders as to which control method is more appropriate from a Benefit Cost Analysis perspective.

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APPENDICES

Appendix A: Survey

Appendix A: Survey

Managing invasive species in British Columbia's grasslands.

What do you think about invasive plant species on British Columbia's Grasslands?

This survey is being conducted by a research team from Thompson Rivers University that includes Dr. Lauchlan Fraser, Dr. Peter Tsigaris, and a Master of Science in Environmental Science student, Adetola Ajayi.

The aim is to examine people's attitudes and perceptions about invasive plant species and their control in British Columbia's grasslands. Your views are very important to us. With the help of your answers, we will explore the issue and potentially develop a future management plan for policymakers.
We appreciate your help!

Consent, Risk, Privacy, and Right to Refuse

Consent: By completing the survey questionnaire, you, the participant are providing your consent for the information to be used for the purpose of this study.

Risk: There are no risks associated with completing the survey.

Privacy and Storage: No identifying information will be collected. Information you provide will be filed and stored in a cabinet at the office of the supervising faculty and after the conclusion of the study, kept for five years and then destroyed.

Right to refuse: You have the right to refuse or cease participation at any time during the survey.

We appreciate your participation in this survey. If you would like to know the results of this research project, please feel free to contact any of us via email (lfraser@tru.ca, ptsigaris@tru.ca, ajayia20@mytru.ca). We will email you a copy of the thesis.
Please note that you must be 18 years or older to complete the survey.

If you consent to participate, please proceed.Grassland invaded by

non-native plant species. Grassland Conservation Council of B.C.

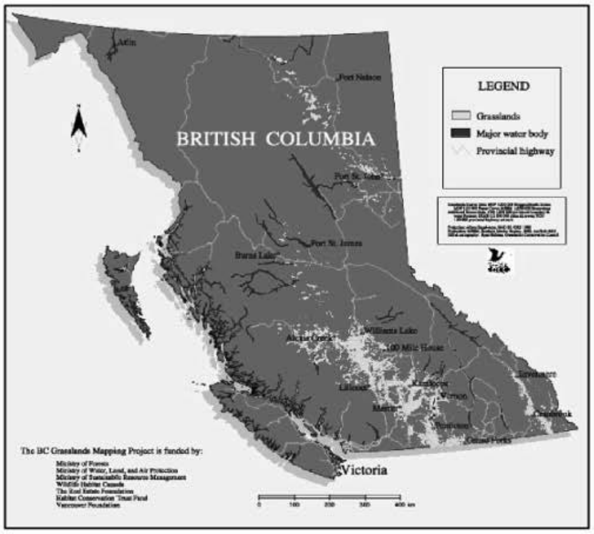
BACKGROUND INFORMATION

Natural grasslands cover less than 1% of the total landmass in British Columbia (B.C.), nevertheless, they support more threatened and endangered plant and animal species than any other habitat type in the province. Most of the grasslands are in the interior of B.C. and are located on Crown land. Native grasslands are significant contributors to ecosystem services examples of which are provisioning services (e.g.; habitat, forage, fresh water), regulating services (e.g.; flood control, carbon sequestration, water purification) , cultural services (e.g.; recreation, aesthetic, spiritual value) and supporting services (e.g.; nutrient cycling, soil formation). Grasslands are threatened, and in recent decades, they have been negatively affected by the invasion of non-native plant species. Preserving grasslands is essential for maintaining species diversity and numerous ecosystem services.

Invasive plant species are non-native plant species introduced into a novel environment with negative ecological, economic or social impacts. The negative impacts that non-native invasive plants have on grasslands include a reduction in the diversity of native plant species, which can lead to a diminishment of quality habitat for invertebrates and animals, loss of forage for wildlife and livestock, a reduction in the aesthetic and recreational value of the grasslands, and a reduced ability for grassland soils to sequester carbon. Carbon sequestration in soils can mitigate global climate change by reducing greenhouse gasses in the atmosphere.

It is estimated that 35% of the grassland ecosystems in B.C. are dominated by non-native herbaceous vegetation, and invasive plants are expected to increase significantly over the next decades if they are not controlled, which would result in more damage to the ecosystem.

Map showing locations of grasslands in B.C.



1. Before receiving this survey, how aware were you of the invasive plant species problem on grasslands in the interior of B.C?

- ◯ Not aware
- ◯ Slightly aware
- ◯ Somewhat aware
- ◯ Very aware
- ◯ Extremely aware

2. Before receiving the survey, which non-native invasive plant have you heard about?

- ☐ Blueweed
- ☐ Common tansy
- ☐ Dalmatian toadflax
- ☐ Hoary alyssum
- ☐ Hounds-tonque
- ☐ Orange Hawkweed
- ☐ Oxeye daisy
- ☐ Rush skeletonweed
- ☐ Spotted knapweed
- ☐ Sulfur cinquefoil
- ☐ None

- ☐ Other (please specify)

Common invasive plants in B.C.

Common tansy

Spotted knapweed

Sulfur cinquefoil

Blue weed

Hoary alyssum

3. How concerned are you about non-native invasive plants on grasslands in the interior of B.C?

- Not concerned
- Slightly concerned
- Somewhat concerned
- Very concerned
- Extremely concerned.

4. How concerned are you about the future long-term risk of

	Not concerned	Slightly concerned	Somewhat concerned	Very concerned	Extremely concerned
Spread of the invasive plant species	○	○	○	○	○
Damage of the grasslands by invasive plant species	○	○	○	○	○
Control measures not being effective in reducing the spread of invasive plant species	○	○	○	○	○

5. In your opinion, what percentage of the grasslands will be invaded over the next decade if there is no management/policy to contain the spread?

- The current approximate 35% invasion
- 40-60%
- 61-80%
- Over 80%
- Don't know

6. How effective is the B.C. Ministry of Forests (responsible for the stewardship of Crown land) in making the public aware of the problem of invasive plant species and why it is occurring.

- ◯ Strongly ineffective
- ◯ Somewhat ineffective
- ◯ Neutral
- ◯ Somewhat effective
- ◯ Strongly effective
- ◯ Not sure

7. How effective is the B.C. Ministry of Forests in motivating the public to do their part to prevent further spread?

- ◯ Strongly ineffective
- ◯ Somewhat ineffective
- ◯ Neutral
- ◯ Somewhat effective
- ◯ Strongly effective
- ◯ Not sure

8. How effective is the B.C. Ministry of Forests in monitoring non-native plant invasion?

- ◯ Strongly ineffective
- ◯ Somewhat ineffective
- ◯ Neutral
- ◯ Somewhat effective
- ◯ Strongly effective
- ◯ Not sure

9. How effective are non-governmental agencies in doing their part to prevent the further spread of invasive plants on grasslands?

- ◯ Slightly ineffective
- ◯ Somewhat effective
- ◯ Somewhat ineffective
- ◯ Strongly effective
- ◯ Neutral
- ◯ Not sure

SECTION 2

Imagine that you are offered choices between control measures for how the British Columbia government responds to the problem of invasive plant species in the interior of British Columbia. Each control measure would span a 10-year period.

These programs would help to control the invasive species on grasslands. Your answers can help the government decide what to do. The possible measures to control the invasive plant species are costly and paid for by increases in taxes.

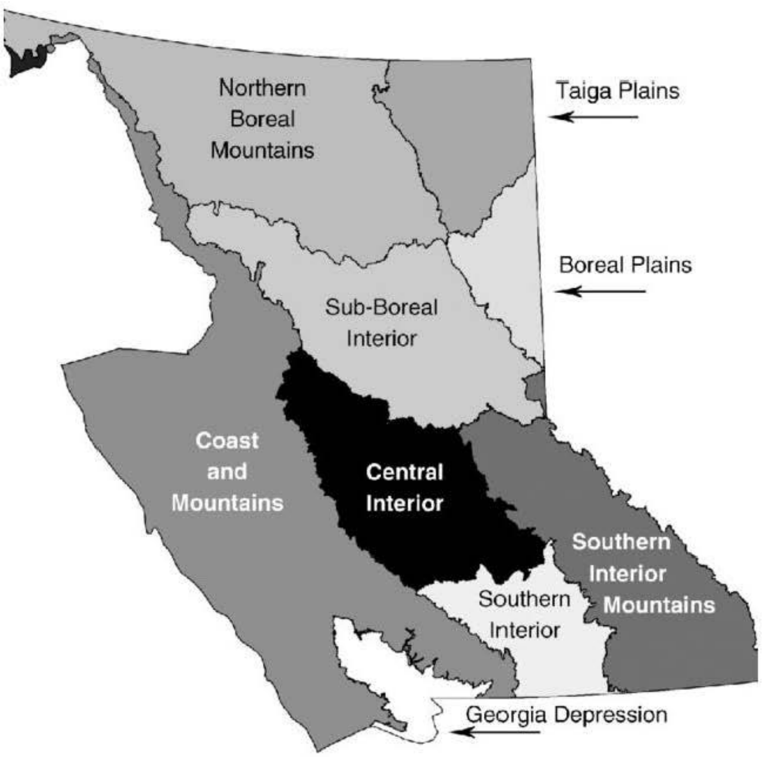
You will be asked to choose your preferred management option from a set of two alternatives as presented on a choice card.

Each choice card will contain two different control policies and an opt-out option (i.e., none of the two controls). The control measures will depend on attributes such as the location of the invasive species, the degree of control, the control measure, and the additional taxes needed to finance the control measure.

Next, we explain the four attributes and their respective levels.

Location of control: Where the non-native invasive plants would be controlled in B.C.

- Northern interior of B.C. (Sub-Boreal Interior and Northern Boreal Mountains,
- Boreal and Taiga Plains) Central interior of B.C. (Cariboo-Chilcotin and Central Interior)
- Southern interior of B.C. (Southern interior and Southern
- interior mountains) Everywhere in the interior of B.C.



Degree of Control: The degree of control of current invasive plant species could be minor, moderate, or major eradication.

Control measures: These are control actions undertaken to reduce the spread of the invasive species over the next decade. These could be:

- Biological control (using natural enemies of the invasive plants to counter them)
- Chemical spraying (this involves spraying herbicides or pesticides to control the invasive plants)
- Targeted grazing (this involves using livestock to achieve invasive plants management goals)

Cost of control: Additional taxes from provincial income taxes will be required to finance the control measure. Your household will have less money to spend on other things if the program goes ahead. This would amount to $25, $50,

$75, or $100 extra per household per year.

Images showing various invasive plants control methods

Chemical control method: This involves using pesticides, herbicides, fungicides, and insecticides to destroy undesired invasive plants.

Biological control method: This involves using natural enemies to reduce the vigour or reproductive potential of invasive plants, e.g., herbivores, plant-attacking insects, mites, and pathogens.

Targeted grazing method: This involves using livestock for grazing on invasive plants for control purposes, e.g., goats, cattle, and sheep.

AN EXAMPLE OF A CHOICE CARD

The following example is for illustration only and will not be used for our research. It is meant to get you acquainted with the choice cards. First, a brief explanation of the three options is provided with a summary table of the two policy options. You can select one of the two or none.

Control policy 1 - Offers a control option for invasive plants with the location of control in the interior of B.C. The invasive control option is chemical spraying for all the grasslands. The degree of control is moderate. Financing such a control option requires a tax increase of $100 annually per household.

Control policy 2 - The location of the control of non-native invasive plant species is in the southern interior only. Targeted grazing will be used to combat this invasion, the degree of control is major and this option will cost $50 in extra taxes per household annually.

Do nothing option - The 'do nothing' option means that you are not satisfied with the choices offered. You may prefer that the government take no extra action. It also means that there will be no extra taxes.

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$50
Location of control	Everywhere in the interior of B.C.	Southern interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Moderate eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ Do Nothing option- I prefer that the government takes NO action. NO additional TAXES

10. Now we will show you five choice cards where we would like you to pick the policy option you would most like to be introduced in B.C. grasslands.

Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$50
Location of control	Everywhere in the interior of B.C.	Everywhere in the interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Major eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 2

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$25
Location of control	Northern interior of B.C.	Southern interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Minor eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 3

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$25
Location of control	Everywhere in the interior of B.C.	Central interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Major eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$25
Location of control	Central interior of B.C.	Everywhere in the interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Moderate eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Northern interior of B.C.	Southern interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

◯ Control policy 1

◯ Control policy 2

◯ I prefer that the government takes NO action. NO additional TAXES

10. Now we will show you five choice cards where we would like you to pick the policy option you would most like to be introduced in B.C. grasslands.

Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$25	$100
Location of control	Central interior of B.C.	Everywhere in the interior of B.C.
Control measure	Biological control	Targeted grazing
Degree of control	Major eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 2

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$50
Location of control	Northern interior of B.C.	Southern interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Minor eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 3

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Northern interior of B.C.	Everywhere in the interior of B.C.
Control measure	Chemical spraying	Biological control
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$75
Location of control	Central interior of B.C.	Southern interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Moderate eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$50	$50
Location of control	Northern interior of B.C.	Southern interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Minor eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

10. Now we will show you five choice cards where we would like you to pick the policy option you would most like to be introduced in B.C. grasslands.

Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$50
Location of control	Everywhere in the interior of B.C.	Southern interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Moderate eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 2

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$50
Location of control	Central interior of B.C.	Everywhere in the interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Moderate eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 3

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$25	$100
Location of control	Northern interior of B.C.	Everywhere in the interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Major eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax costs for control	$50	$75
Location of control	Southern interior of B.C.	Everywhere in the interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$25	100
Location of control	Northern interior of B.C.	Central interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Major eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

10. **Now we will show you <u>five</u> choice cards where we would like you to pick the policy option you would most like to be introduced in B.C. grasslands.**

Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$100	$50
Location of control	Everywhere in the interior of B.C.	Southern interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Major eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- Control policy 1
- Control policy 2
- I prefer that the government takes NO action. NO additional TAXES

Choice card 2

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$25	$100
Location of control	Everywhere in the interior of B.C.	Central interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Major eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- Control policy 1
- Control policy 2
- I prefer that the government takes NO action. NO additional TAXES

Choice card 3

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$25
Location of control	Central interior of B.C.	Everywhere in the interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Moderate eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Southern interior of B.C.	Northern interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Minor eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

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- ◯ Control policy 2
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Choice card 5

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$25	$100
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Control measure	Targeted grazing	Chemical spraying
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Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

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Additional tax per year for control	$25	$100
Location of control	Everywhere in the interior of B.C.	Central interior of B.C.
Control measure	Chemical spraying	Biological control
Degree of control	Major eradication	Moderate eradication

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Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$50
Location of control	Everywhere in the interior of B.C.	Southern interior of B.C.
Control measure	Targeted grazing	Chemical spraying
Degree of control	Moderate eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- Control policy 1
- Control policy 2
- I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$75	$75
Location of control	Northern interior of B.C.	Southern interior of B.C.
Control measure	Biological control	Chemical spraying
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- Control policy 1
- Control policy 2
- I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$25
Location of control	Central interior of B.C.	Southern interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Moderate eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

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Control measure	Targeted grazing	Chemical spraying
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Choice card 2

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$25	$100
Location of control	Central interior of B.C.	Northern interior of B.C.
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Degree of control	Major eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

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- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$25
Location of control	Everywhere in the interior of B.C.	Central interior of B.C.
Control measure	Targeted grazing	Chemical spraying
Degree of control	Major eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$75	$50
Location of control	Southern interior of B.C.	Everywhere in the interior of B.C.
Control measure	Chemical control	Biological control
Degree of control	Moderate eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

◯ Control policy 1

◯ Control policy 2

◯ I prefer that the government takes NO action. NO additional TAXES

10. **Now we will show you five choice cards where we would like you to pick the policy option you would most like to be introduced in B.C. grasslands.**

Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Southern interior of B.C.	Northern interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- Control policy 1
- Control policy 2
- I prefer that the government takes NO action. NO additional TAXES

Choice card 2

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Northern interior of B.C.	Northern interior of B.C.
Control measure	Biological control	Targeted grazing
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- Control policy 1
- Control policy 2
- I prefer that the government takes NO action. NO additional TAXES

Choice card 3

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Northern interior of B.C.	Northern interior of B.C.
Control measure	Chemical spraying	Targeted grazing
Degree of control	Minor eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$50
Location of control	Everywhere in the interior of B.C.	Everywhere in the interior of B.C.
Control measure	Targeted grazing	Biological control
Degree of control	Moderate eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$25	$100
Location of control	Everywhere in the interior of B.C.	Central interior of B.C.
Control measure	Biological control	Targeted grazing
Degree of control	Minor eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

10. **Now, we will show you five choice cards where we would like you to pick the policy option you would most like to be introduced in B.C. grasslands.**

Think about what is important to you and how much each option could cost. Please look at each set of choices independently of the previous cards.

Choice card 1

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$50	$50
Location of control	Southern interior of B.C.	Northern interior of B.C.
Control measure	Chemical control	Targeted grazing
Degree of control	Minor eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 2

Attributes	Control policy I	Control policy 2
Additional tax per year for control	$75	$25
Location of control	Southern interior of B.C.	Northern interior of B.C.
Control measure	Chemical spraying	Biological control
Degree of control	Moderate eradication	Major eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 3

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$100	$25
Location of control	Central interior of B.C.	Northern interior of B.C.
Control measure	Targeted grazing	Targeted grazing
Degree of control	Moderate eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 4

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$25	$100
Location of control	Southern interior of B.C.	Central interior of B.C.
Control measure	Targeted grazing	Chemical spraying
Degree of control	Major eradication	Moderate eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Choice card 5

Attributes	Control policy 1	Control policy 2
Additional tax per year for control	$50	$75
Location of control	Southern interior of B.C.	Northern interior of B.C.
Control measure	Chemical spraying	Biological control
Degree of control	Minor eradication	Minor eradication

Using the choice card above, which of the following options for invasive plant control during the next 10 years would you prefer?

- ◯ Control policy 1
- ◯ Control policy 2
- ◯ I prefer that the government takes NO action. NO additional TAXES

Answer question 11, ONLY if you selected a control policy in any of the five choice cards.

11. Please rank the attributes according to their importance for your choices. (From 1 being the most important, to 4 being the least important)

⬍	Additional tax costs for households (per year)
⬍	
⬍	Type of invasive plant control measures
⬍	

Answer question 12, ONLY if you selected no government action on ALL of the five choice cards

12. Why did you select no government action on ALL of the five choice cards?

- ☐ I believe the private sector can control the problem of invasive plants better than the government
- ☐ Invasive plants management should be financed exclusively by the private sector
- ☐ The issue of invasive plants control is not important or interesting to me
- ☐ I do not believe that the proposed control measure will be effective
- ☐ Most important aspects of the issue are missing or are misrepresented
- ☐ Other (please specify)

SECTION 3- DEMOGRAPHICS

Now we would like you to answer some questions about yourself. No identifying information will be collected. Any information you provide will be filed and stored in a cabinet at the office of the supervising faculty and after the conclusion of the study, kept for 5 years and then destroyed.

13. To which age category do you belong?

- ◯ 18 to 24
- ◯ 25 to 34
- ◯ 35 to 44
- ◯ 45 to 54
- ◯ 55 to 64
- ◯ 65 to 74
- ◯ 75 years and over

14. What is your gender?

- ◯ Male (including transgender male)
- ◯ Female (including transgender female)
- ◯ Non-binary / Non-conforming
- ◯ Prefer not to say

15. Did you spend at least part of your childhood growing up in a rural area?

- ◯ Yes
- ◯ No

16. What type of community or area do you live in?

- ◯ Rural (population less than 1,000)
- ◯ Village (population between 1,001 and 2,500)
- ◯ Town (population between 2,501 and 5,000)

◯ Small city (population between 5,001 and 50,000)

◯ Medium-sized city (population between 50,001 and 250,000)

Larger city (population over 250,001) ◯

17. Where in B.C. do you live?

- Vancouver Island
- Lower Mainland
- Southern interior of B.C.
- Southern interior mountains
- Central interior of B.C.
- Northern B.C.

18. What is the highest level of education that you have completed?

- Some High school or less
- High school graduate
- Some College/Vocational or Trade School /University
- College/Vocational or Trade school graduate
- University graduate (Bachelor's degree)
- Post Graduate Studies

19. In which range does your household's gross annual (before tax) income fall?

- Less than $ 20,000
- $20,001 to $30,000
- $30,001 to $ 40,000
- $40,001 to $50,000
- $50,001 to $60,000
- $60,001 to $70,000
- $70,001 to $80,000
- $80,001 to $90,000
- $90,001 to $100,000
- $100,001 or more
- Refuse to disclose my household income

20. **Do you belong to any environmental or ecological organization?**

- Y es
- N o

21. **Please provide any additional comments that you may want to mention.**

This is the end of the survey. Thank you for participating.

Appendix B: Description of different invasive plants in B.C.

S/N	Invasive plants	Scientific name	Description
1.	Blue weed	Echium vulgare	E. vulgare grows 30-80cm tall, with blue funnel-shaped flowers on top of the plant. Leaves and stems are usually very hairy.
2.	Common tansy	Tanacetum vulgare	T. vulgare is a perennial herbaceous flowering plant with yellow button-like flowers, which can grow up to 1.5m high. It spreads via roots and seeds.
3.	Dalmatian toadflax	Linaria dalmatica	L. dalmatica is a herbaceous, short-lived perennial plant. It has unique yellow flowers with an orange centre. It can crowd out native plants reducing forage quality.
4.	Hoary alyssum	Berteroa incana	B. incana is a biennial herbaceous flowering plant, usually hairy, with a stem 30 to 80cm tall and basal leave 8 to 10cm long.
5.	Hounds tonque	Cynoglossum officinale	C. officinale either be annual or bi-annual. Leaves are often greyish and softly-haired. Flowers are reddish-purple funnel shaped.
6.	Orange hawkweed	Pilosella aurantiaca	P. aurantiaca is a perennial flowering plant; all parts of the plant exude a milky juice. Stem and leaves are covered with blackish short, stiff hairs.
7.	Oxeye daisy	Leucanthemum vulgare	L. vulgare is a perennial herb that grows to a height of 80cm with a creeping underground rhizome. The lower part of the stem is hairy.
8.	Rush skeletonweed	Chondrilla juncea	C. juncea is a thin spindly flowering plant reaching a meter in height. It reproduces by seed and also by cloning itself at the root.
9.	Spotted knapweed	Centaurea stoebe	C. stoebe is a biennial or short-lived perennial plant; the leaves are usually pale and deeply lobed, covered in fine short hairs.
10.	Sulfur cinquefoil	Potentilla recta	P. recta is a tufted plant with a woody taproot, a perennial herb. Stems are erect and about 80cm tall.
11.	Japanese knotweed	Reynoutria japonica	R. japonica is a herbaceous perennial plant with hollow stems and distinct raised nodes with an appearance of a bamboo.
12.	Giant hogweed	Heracleum mantegazzianum	H. mantegazzianum is a monocarpic perennial herbaceous plant that typically grows to heights of 2 to 5m. Leaves are incised and deeply lobed; mature plants have huge leaves between 1 and 1.5m wide.
13.	Cheatgrass	Bromus tectorum	B. tectorum is an annual winter grass with a smooth and slender stem; leaves are usually hairy and typically 40 to 90 cm tall.
14.	Purple loosestrife	Lythrum salicaria	L. salicaria can grow up to 1 to 2m tall and 1.5m wide, with numerous erect stems growing from a single woody root mass. It crowds out native plants reducing biodiversity
15.	Silverleaf nightshade	Solanum elaeagnifolium	S.elaeagnifolium is a perennial of about 10cm to 1m in height. Leaves and stems are covered with downy hairs, usually up to 15cm long and 0.5 to 2.5cm wide.
16.	Leafy spurge	Euphoria esula	E. esula is an herbaceous perennial plant growing to about 1 to 1.2m tall with several stems branched from the base. Stems are smooth, hairless, or just slightly hairy.

Appendix C: A Simple Model for valuation of attributes of control policies

Appendix C shows the estimated coefficients from the MNL and Mixed Logit models without the socioeconomic and attitudinal variables. The results without the socioeconomic and attitudinal variables are very similar with respect to the attributes and their levels. This is not unexpected since the socioeconomic variables interact only with the alternative specific constants. When people make selection of the attributes they do not consider their socio-economic status. Hence the prices of the attributes remain almost unaffected. However, the packages will be impacted since the alternative specific constants and their interaction with the socioeconomic variable play an important role in the valuation of packages.

Table C.1: Multinomial logit model: Models for valuation of attributes of control policies

	All observation		Vancouver Island		Lower Mainland		Interior B.C.	
Extra taxes	-0.016	***	-0.015	***	-0.018	***	-0.013	***
	[-0.018,-0.014]		[-0.018,-0.011]		[-0.020,-0.016]		[-0.017,-0.010]	
Northern interior B.C.	-0.365	***	-0.371	***	-0.269	***	-0.637	***
	[-0.467,-0.264]		[-0.610,-0.131]		[-0.401,-0.137]		[-0.861,-0.413]	
Central interior B.C.	-0.660	***	-0.555	***	-0.590	***	-0.965	***
	[-0.774,-0.546]		[-0.811,-0.299]		[-0.741,-0.440]		[-1.210,-0.720]	
Southern interior B.C.	-0.652	***	-0.958	***	-0.496	***	-0.898	***
	[-0.763,-0.542]		[-1.228,-0.688]		[-0.639,-0.354]		[-1.141,-0.654]	
Biological control	0.853	***	0.941	***	0.833	***	0.900	***
	[0.755, 0.951]		[0.715, 1.167]		[0.704, 0.961]		[0.686, 1.113]	
Targeted grazing	1.275	***	1.520	***	1.161	***	1.397	***
	[1.143, 1.407]		[1.204, 1.836]		[0.990, 1.332]		[1.110, 1.684]	
Moderate eradication	0.542	***	0.333	**	0.586	***	0.676	***
	[0.413, 0.671]		[0.025, 0.641]		[0.418, 0.753]		[0.393, 0.959]	
Major eradication	0.399	***	0.191		0.537	***	0.212	*
	[0.295, 0.503]		[-0.048, 0.430]		[0.401, 0.673]		[-0.017, 0.441]	
ASC0: No policy:	-1.385	***	-1.431	***	-1.394	***	-1.345	***
	[-1.454,-1.316]		[-1.594,-1.268]		[-1.485,-1.303]		[-1.493,-1.196]	
Number of observations	14,925		2,799		8,742		3,191	
χ^2	2750.20		550.71		1613.31		605.12	

*** p<.01, ** p<.05, * p<.1

Table C.2: Implicit prices of attributes of control policies

All observations				Vancouver Island			
	WTP per unit change		[95% conf interval]		WTP per unit change		[95% conf interval]
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior	-22	***	(-29, -15)	Northern interior	-25	**	(-44,-6)
Central interior	-40	***	(-49, -32)	Central interior	-38	***	(-60,-16)
Southern interior	-40	***	(-49, -31)	Southern interior	-65	***	(-95, -36)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	52	***	(46,58)	Biological control	64	***	(47,82)
Targeted grazing	79	***	(71,86)	Targeted grazing	104	***	(82,126)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	33	***	(26,40)	Moderate eradication	22	**	(4,41)
Major eradication	24	***	(18,31)	Major eradication	13		(-3,29)
Lower Mainland				**Interior of B.C.**			
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior.	-15	***	(-23,-7)	Northern B.C.	-47	***	(-70,-24)
Central interior	-33	***	(-43, -23)	Central interior	-71	***	(-100,-43)
Southern interior	-28	***	(-37, -18)	Southern interior	-66	***	(-96,-37)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	47	***	(40,53)	Biological control	66	***	(49,84)
Targeted grazing	65	***	(57,73)	Targeted grazing	103	***	(80,127)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	33	***	(25,40)	Moderate eradication	50	***	(33,67)
Major eradication	30	***	(22,38)	Major eradication	15	*	(-1,32)

Table C.3: Willingness to pay per year per household for control policies: All observations and moderate eradication.

		Simple Model			Slightly concerned = 2			Concerned = 2.9			Extremely concern = 5		
Location of control	Type of control	WTP		95% CI	WTP		95% CI	WTP		95% CI	WTP		95% CI
Everywhere in interior B.C.	Chemical	119	***	(108,130)	92	***	(83,102)	127	***	(115,139)	208	***	(186,230)
	Biological	172	***	(159,186)	145	***	(133,157)	180	***	(166,194)	261	***	(236,285)
	Targeted grazing	198	***	(185,212)	171	***	(160,183)	206	***	(192,220)	287	***	(262,312)
Northern interior	Chemical	96	***	(86,107)	70	***	(60,79)	104	***	(93,115)	185	***	(165,205)
	Biological	149	***	(138,160)	123	***	(113,133)	157	***	(145,169)	238	***	(216,260)
	Targeted grazing	176	***	(164,187)	149	***	(138,159)	183	***	(171,195)	264	***	(242,286)
Central interior	Chemical	78	***	(70,87)	51	***	(43,60)	86	***	(77,95)	167	***	(148,185)
	Biological	131	***	(121,141)	104	***	(95,114)	139	***	(129,149)	220	***	(199,240)
	Targeted grazing	157	***	(148,167)	130	***	(121,139)	165	***	(155,175)	246	***	(225,266)
Southern interior	Chemical	79	***	(70,87)	52	***	(42,61)	86	***	(77,95)	167	***	(149,185)
	Biological	132	***	(122,141)	105	***	(95,114)	139	***	(129,150)	220	***	(200,240)
	Targeted grazing	158	***	(147,168)	131	***	(121,141)	165	***	(154,176)	246	***	(226,266)

Table C.4: Mixed Logic Model: Model for valuation of attributes of control policies

	All observation		Vancouver Island		Lower Mainland		Interior B.C.	
Extra taxes	-0.006	***	-0.004	*	-0.009	***	-0.003	
	[-0.008,-0.005]		[-0.009, 0.000]		[-0.011,-0.006]		[-0.007, 0.001]	
Northern B.C.	-0.295	***	-0.261	*	-0.220	***	-0.565	***
	[-0.422,-0.168]		[-0.552, 0.029]		[-0.384,-0.056]		[-0.856,-0.274]	
Central interior	-0.218	***	-0.049		-0.174	**	-0.479	***
	[-0.334,-0.101]		[-0.320, 0.221]		[-0.327,-0.021]		[-0.733,-0.225]	
Southern interior	-0.239	***	-0.352	**	-0.197	**	-0.305	*
	[-0.381,-0.098]		[-0.688,-0.015]		[-0.379,-0.014]		[-0.621, 0.010]	
Biological control	0.862	***	0.996	***	0.766	***	1.095	***
	[0.752, 0.973]		[0.739, 1.252]		[0.624, 0.907]		[0.836, 1.354]	
Targeted grazing	1.011	***	1.219	***	0.863	***	1.244	***
	[0.874, 1.149]		[0.885, 1.552]		[0.686, 1.039]		[0.935, 1.554]	
Moderate eradication	0.313	***	0.132		0.371	***	0.385	***
	[0.187, 0.439]		[-0.171, 0.434]		[0.209, 0.533]		[0.097, 0.673]	
Major eradication	0.557	***	0.504	***	0.655	***	0.408	***
	[0.429, 0.685]		[0.199, 0.808]		[0.489, 0.821]		[0.121, 0.695]	
ASC0: No action	-0.302	***	-0.114		-0.438	***	-0.028	
	[-0.489,-0.115]		[-0.554, 0.327]		[-0.679,-0.197]		[-0.456, 0.400]	
Number of observations	14,898		2,788		8,716		3,177	
χ^2	1115.21	***	257.97	***	626.69	***	262.22	***

*** p<.01, ** p<.05, * p<.1

Table C.5: Simple Mixed Logit model: Implicit prices of attributes of control policies

All observations				Vancouver Island			
	WTP per unit change		[95% conf interval]		WTP per unit change		[95% conf interval]
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior	-45	***	(-68, -23)	Northern interior	-64		(-161,32)
Central interior	-33	***	(-54, -13)	Central interior	-12		(-79, 55)
Southern interior	-37	***	(-59, -14)	Southern interior	-86		(-203, 30)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	133	***	(89,178)	Biological control	245	*	(-38,529)
Targeted grazing	156	***	(113,200)	Targeted grazing	300	*	(-5,606)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	48	***	(29,67)	Moderate eradication	32		(-37,101)
Major eradication	86	***	(50,121)	Major eradication	124		(-47,296)
Lower Mainland				Interior of B.C.			
Location (base level: Everywhere in B.C.)				Location (base level: Everywhere in B.C.)			
Northern interior.	-25	**	(-45,-5)	Northern B.C.	-211		(-547,125)
Central interior	-20	**	(-39,-2)	Central interior	-179		(-470,112)
Southern interior	-23	**	(-44,-1)	Southern interior	-114		(-305,77)
Type of control (base level: Chemical spraying)				Type of control (base level: Chemical spraying)			
Biological control	90	***	(57,122)	Biological control	409		(-245,1064)
Targeted grazing	101	***	(72,130)	Targeted grazing	464		(-232,1162)
Degree of control (base case: Minor eradication)				Degree of control (base case: Minor eradication)			
Moderate eradication	43	***	(25,61)	Moderate eradication	143		(-57,344)
Major eradication	77	***	(44,109)	Major eradication	152		(-121,426)

Table C.6: Willingness to pay per year per household for control policies: All observations and moderate eradication.

		Model 1: Simple MNL Model			Model 2: Simple Mixed Logit Model		
Location of control	Type of control	WTP		95% CI	WTP		95% CI
Everywhere in interior B.C.	Chemical	119	***	(108,130)	95	***	(71,119)
	Biological	172	***	(159,186)	229	***	(179,279)
	Targeted grazing	198	***	(185,212)	252	***	(205,298)
Northern interior	Chemical	96	***	(86,107)	49	***	(23,75)
	Biological	149	***	(138,160)	183	***	(143,223)
	Targeted grazing	176	***	(164,187)	206	***	(169,243)
Central interior	Chemical	78	***	(70,87)	61	***	(39,84)
	Biological	131	***	(121,141)	195	***	(154,236)
	Targeted grazing	157	***	(148,167)	218	***	(180,255)
Southern interior	Chemical	79	***	(70,87)	58	***	(38,78)
	Biological	132	***	(122,141)	192	***	(147,236)
	Targeted grazing	158	***	(147,168)	215	***	(172,257)

Appendix D: Other issues raised by respondents in the survey.

1. Although I now recognize the issue of invasive plants here in B.C., I believe there are other much more important major issues here in B.C. that should be dealt with by the government. In this current state of inflation, where buying stuff like groceries is impossible and is extremely overpriced, taking up more taxes from the people for the issue of invasive plants is just not a high priority currently. Maybe in the future, when trying to live won't be as expensive as it is currently here in B.C., we will be able to pay more attention to the issue of invasive plants.
2. The proposed methods are impractical; when these plants are removed, the vital ground cover is removed, and landslides occur. The grazing of animals would be a better option as no harm is done to the land.
3. Because taxes will increase, things are already hard to afford. I will have to say no.
4. I don't have enough information.
5. The cost of living is already high, and we are going into a time when we need to manage a real crisis before we take on another.
6. Homelessness is more important than the future of grasslands.
7. Already too expensive to live in B.C.
8. B.C. is the most over-taxed province in Canada, and people cannot afford to pay more taxes.
9. We are already taxed to the limit. Can't afford more taxes taken out of my household.
10. More information is required. Are the taxes to be levied regionally? provincially?
11. Not all new species are bad, go back to the ice age to determine what was native at that time.
12. I do not believe we should be shelling out dollars for this.
13. The government should use the money it already gets we pay enough as it is.
14. Don't believe chemicals are beneficial.
15. The government takes more than enough taxes already.
16. Homelessness is more important to eradicate.
17. It would take politics, redirected taxes, and private donations to deal with this issue.
18. I am not in favour of chemicals.
19. People are struggling to afford food & keep their homes and can't afford this big a tax for one thing among so many other issues.

20. Too costly.
21. We pay more than enough taxes in B.C. to pay even more for the government to take care of the environment and its natural resources. I would love to discuss the methods if there is no extra taxation for the population.
22. We are paying too many taxes already, so don't want any more taxes.
23. Enough is enough with tax increases.
24. The government should address homelessness, which is a human right. The houses are about 40 owned by investors milking the public. The invasive population of the rich is plaguing the public. Invasive plants are no danger to me.
25. The government should take money from the enormous profits of BCLC.

Appendix E: Tables showing the importance of attributes for the public and stakeholders.

Table E.1: Importance of attributes in deciding choice from the public.

			Type of control Q11.2	Degree of control Q11.4	Extra taxes Q11.1	Location of spread Q11.3
Attributes	Q11	Mean Response	2.06	2.52	2.63	2.75
Type of control	Q11.2	2.06		0.000	0.000	0.000
Degree of control	Q11.4	2.52			0.111	0.000
Extra taxes	Q11.1	2.63				0.093
Location of spread	Q11.3	2.75				

Note: Individual confidence level 98.97%. p-values are indicated.

Table E.2: Importance of attributes in deciding choice from stakeholders.

			Degree of control Q11.4	Type of control Q11.2	Location of spread Q11.3	Extra Taxes Q11.1
Attributes	Q11	Mean Response	1.76	2.18	2.66	3.47
Degree of control	Q11.4	1.76		0.074	0.000	0.000
Type of control	Q11.2	2.18			0.032	0.000
Location of spread	Q11.3	2.66				0.000
Extra taxes	Q11.1	3.47				

Note: Individual confidence level 98.97%. p-values indicated.

Table E.3: Comparing the ranking of the same attributes between the public and stakeholders.

				Stakeholders			
				Extra Taxes	Type of control	Location of spread	Degree of control
	Attributes	Q11	Mean Response	3.47	2.18	2.66	1.76
Public	Extra taxes	Q11.1	2.63	0.000			
Public	Type of control	Q11.2	2.06		0.392		
Public	Location of spread	Q11.3	2.75			0.460	
Public	Degree of control	Q11.4	2.52				0.000

Note: p-values are indicated in the table.