POLICY ALTERNATIVES FOR ENGLISH IVY MANAGEMENT IN WASHINGTON STATE

by

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ABSTRACT

Policy Alternatives for English Ivy Management in Washington State

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Previous invasive species research has utilized expert opinion surveys to determine optimal economic policies for an agricultural pest and to identify policy preferences for horticultural invasive species. The purpose of this study is to explore the efficacy of expert opinion surveys as a research tool for analyzing policy alternatives for a specific horticultural invasive plant species. Weed board and natural resource professionals in Washington State responded to survey questions regarding the effectiveness, cost-effectiveness, and political feasibility of policies for managing English ivy (*Hedera* spp.), a horticultural invader threatening forest ecosystems in western portions of the state. Comparing favorable and unfavorable responses for a series of policy alternatives using a Chi-square test elucidated the policies garnering the highest degree of consensus. The policy alternative regarding education and localized control efforts (policy 1) received the highest ranking for all three evaluation criteria. The second most highly-favored policy option was voluntary curtailment of English ivy sales in nurseries (policy 4). Although results for cost-effectiveness and political feasibility were similar between policies 1 and 4, the proportion of favorable responses for the effectiveness of policy 4 was significantly lower than for policy 1 (χ^2=13.48, $p<0.001$). Future research could utilize focus groups or follow-up surveys to explore the rationale for policy preferences as well as establish implementation details for the most favorable policy.

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1. Literature Review

Non-native invasive species are organisms introduced from outside a region that disperse rapidly without direct human assistance (Evans et al. 2008). Invasive plants in Washington State can negatively impact ecological communities and cause millions of dollars in damage. Statewide management efforts prioritize new invaders that are not widely-distributed throughout the state and could pose a major threat to public health, ecological communities, and local businesses (NWCB 2010b). County weed boards, local governments, and nonprofit organizations often opt to control a number of widespread invaders in addition to the state's designated priority species.

English ivy (*Hedera helix* and *Hedera hibernica*[*]) is an invasive species in western Washington that disrupts ecological processes. Climbing English ivy, sometimes reaching up to 90 feet, can add considerable weight to trees (Figure 1.1) (Waggy 2010). Ivy can cover up tree leaves and hinder the process of photosynthesis (Swearingen and Diedrich 2006). English ivy can also host bacterial leaf scorch (*Xylella fastidiosa)*, a pathogen harmful to many native tree species (Swearingen and Diedrich 2006). Tree stress and death leads to public safety hazards in the form of falling trees and branches. Tree losses also reduce arboreal ecosystem services, such as air purification, stormwater infiltration, and aesthetics.

[*] The common name for *Hedera hibernica* is Irish ivy but most natural resource managers in Washington State continue to refer to all invasive ivy as English ivy.

English ivy's contribution to tree death causes gaps in forest canopies and impacts understory communities (Waggy 2010). In a study of Seattle Parks, Dlugosch (2005) observed that areas with English ivy had a smaller percent cover of native species than non-invaded areas. Some studies indicate English ivy may increase soil nitrogen levels at the expense of native plants reliant on low-nutrient conditions (Waggy 2010). The displacement of native shrubs and young trees likely reduces food and shelter for native fauna. Okerman (2000) employs the term "ivy deserts" to describe English ivy monocultures in forest ecosystems.

Figure 1.1. Climbing English ivy. Climbing ivy can cause stress to trees (left). Cutting ivy at the base of trees kills ivy in the canopy (right).

Photos: Alison Baur

Urban restoration efforts focus heavily on English ivy removal; meanwhile, the plant's reintroduction continues through horticultural practices. This study investigates the effectiveness, affordability, and political feasibility of policy alternatives to manage English ivy through a review of academic literature and a survey to natural resource and weed board professionals.

There are numerous components involved in an invasive species policy analysis:

1) Species, habitat, or pathway characteristics contributing to invasion success;
2) Economic costs of invasive species and regulatory mechanisms;
3) Risk assessment protocols for prioritizing management;
4) Benefits and drawbacks of management strategies;
5) Ethical dilemmas associated with management;
6) And current international, federal, and state-level policies.

This literature review takes an interdisciplinary approach to invasive species policy considerations drawing from the fields of invasion ecology, restoration ecology, population biology, geography, economics, political science, and philosophy. The scope of research ranges from general examinations of invasive species to English ivy-specific studies.

Invasion Ecology

A number of studies investigate the life history traits intrinsic to invasive species. Reichard and Hamilton (1997) used classification tree and discriminate analyses to create a hierarchical predictive model of woody plant invasiveness. The results suggested that the primary determinant of invasion success is whether or not a plant invaded elsewhere; key traits include perfect flowers (containing both stamens and carpels), vegetative reproduction, and a lack of pre-germination requirements (Reichard and Hamilton 1997). Pyšek and Richardson (2007) also examined invasive characteristics. The authors reviewed 18 academic studies and determined that rapid growth, high fecundity, and large specific leaf area are common attributes among invasive plants (Pyšek and Richardson 2007).

English ivy demonstrates many characteristics intrinsic to invaders. While originally from Eurasia, English ivy is now invasive to parts of South America, Australia, New Zealand, and 27 states in the United States (Invasive Species Specialist Group 2005). The species reproduces copiously, exhibiting vegetative growth in its juvenile stage (Figure 1.2.) and sexual reproduction as an adult (Figure 1.3.) (Waggy 2010). Broken pieces of its stems or roots can grow independently (Swearingen and Diedrich 2006). English ivy has perfect flowers (Waggy 2010). The pre-germination requirements of English ivy seeds remain unclear, but it is likely the seeds must go through scarification within avian digestive tracts to achieve viability (Waggy 2010). In a review of English ivy studies, Waggy (2010) found that the plant's growth rates vary by habitat type but tend to increase in moist areas. Ivy's climbing ability permits its leaves to

increase photosynthesis with closer proximity to sunlight (Waggy 2010). English ivy's life history characteristics contribute to its competitive advantage over many native plant species.

Figure 1.2. English ivy (*Hedera* spp.) in its juvenile stage.
Photo: Alison Baur

Concepts from population biology explain the process of ecological invasions. The novel weapons hypothesis elucidates how certain invaders alter an environment to suit their needs (Hufbauer and Torchin 2007). An example of a novel weapon is allelopathy, or a plant's ability to alter soil chemistry at the detriment of other species. While some research indicates English ivy increases soil nitrogen levels, other studies question its overall allelopathic effects. Biggerstaff and Beck (2007a) determined English ivy had a minimal allelopathic impact on the regeneration of lanceleaf coreopsis (*Coreopsis lanceolata*), a

wildflower common to the southeastern United States. Another novel weapon is the moderate toxicity of English ivy's leaves and fruit (Swearingen and Diedrich 2006). The glycoside hederin toxin in ivy berries increases the likelihood birds will regurgitate the seeds and facilitate dispersal (National Park Service 2010).

A second population biology theory pertaining to invasions is the "empty niche hypothesis". The hypothesis infers that a habitat with less species diversity is more prone to invasion because invaders capitalize on underutilized resources, including sunlight, soil nutrients, or water. Hufbauer and Torchin (2007) claim the hypothesis explains some invasions better than others. Interactions between species in an ecosystem also influence the invasion process. Invaders often take advantage of mutualists, such as pollinators, in a process known as invasional meltdown (Hufbauer and Torchin 2007). Wasps, bees, and flies all pollinate English ivy flowers (Invasive Species Specialist Group 2005). Dispersers of English ivy seeds include Cedar Waxwings (*Bombycilla cedrorum*), American Robins (*Turdus migratorius*), Stellar Jays (*Cyanocitta stelleri*), Mockingbirds (*Mimus* spp.), European Starlings (*Sturnus vulgaris*), and House Sparrows (*Passer domesticus*) (Swearingen and Diedrich 2006). As a primary consumer of English ivy berries, European Starlings are also invasive and often out-compete native bird species (Waggy 2010).

Genetics are another factor in the invasion process. Sakai et al. (2001) explain that limited genetic diversity among introduced species at first hinders population growth due to bottleneck effects and genetic drift. With greater propagule pressure (frequency and magnitude of introductions), genetic diversity

increases within a population, making it more resilient (Sakai et al. 2001). In a study of primrose (*Primula vulgaris* Huds.) in Belgium, Endels and authors (2007) found that larger populations were more viable, even when confronting genetic and environmental stochasticity.

Figure 1.3. English ivy (*Hedera* spp.) in its adult stage.
Photo: Alison Baur

English ivy's phenotypic plasticity (genetic adaptability) contributes to its invasion success. There are 13 species and 400 cultivars of *Hedera,* although not all are considered invasive (Clarke et al. 2006). Clarke and colleagues (2006) analyzed the taxonomic identity of 58 *Hedera* populations in Oregon, Washington, and British Columbia. Genetic profiles revealed 85 % of the sampled ivy was *H. hibernica* and 15% was *H. helix* "Calfornia", "Pittsburgh", "Star" or other hybrids (Clarke et al. 2006). The authors claim many invasive

English ivy cultivars derived from hybridization and mutation (Clarke et al. 2006).

In addition to the invader's traits and ecological interactions, another contributor to invasion success is landscape structure. In a comparison of the spatial distributions of invasive and non-invasive alien plants in California, Dark (2004) identified exotic species most often in regions with low elevations, high road density, and high native plant species richness. Roads likely increase invasive plant dispersal by acting as corridors for plant and seed transport (Kowarik and von der Lippe 2007). A combination of natural and anthropogenic landscape features can serve to predict the likelihood of invasion in a particular location.

Similarly, studies investigate the environmental factors pertaining to English ivy's distribution. In California, English ivy favors elevations below 3,300 feet (Waggy 2010). The presence of English ivy correlates with areas of high road density, such as urban and suburban forests (Clarke et al. 2006). In Washington State, the Noxious Weed Control Board (NWCB) describes ivy habitat as landscaped areas, disturbed forests, fields, hedgerows, and coastal areas (NWCB 2010a). The Washington State Department of Agriculture's English ivy distribution map indicates that ivy is most common west of the Cascade Mountain Range (Figure 1.4.).

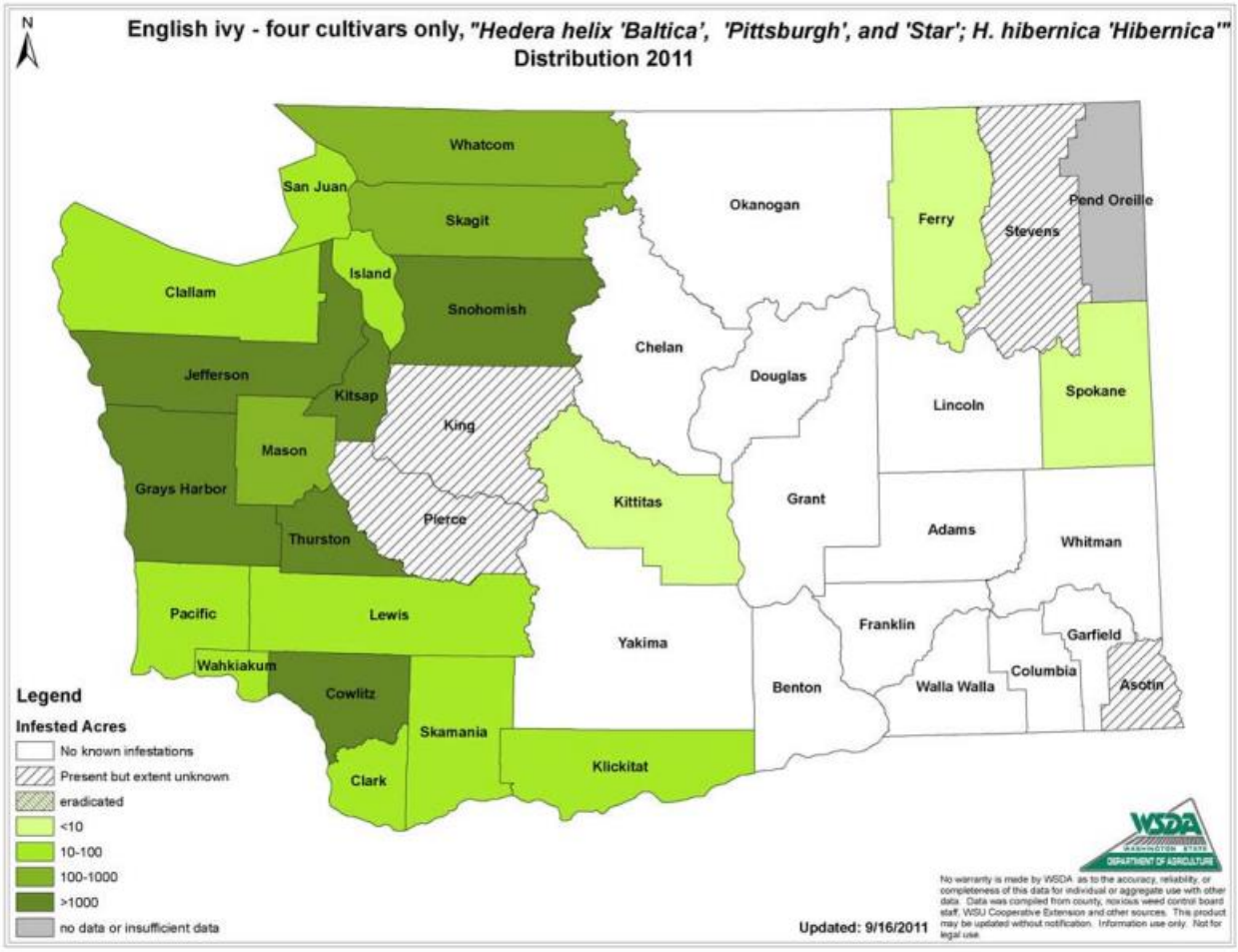

Figure 1.4. The Washington State Department of Agriculture (WSDA) English ivy distribution map.

Retrieved from http://www.nwcb.wa.gov/siteFiles/English%20Ivy%202011.pdf

Anthropogenic Dispersal

Non-native species introductions have occurred throughout history, but current rates are unprecedented due to globalized trade and travel (Ielmini et al. 2012). Ecologist Gordon Orions coined the term "homogocene" to describe the extensive anthropogenic dispersal of species (Ielmini et al. 2012). Kowarkik and von der Lippe (2007) claim an understanding of dispersal vectors according to

human motivation is helpful for invasive species management. Various studies identify anthropogenic drivers of invasive species dispersal including trade, disturbance, bureaucratic land use incentives, and preferences for utilitarian and medicinal plants (Meyerson and Mooney 2007, Robbins 2004). In a two-year experimental study of understory plants in a riparian forest, Von Holle and Simberloff (2005) determined that propagule pressure (frequency and magnitude of introductions) is a significant determinant of invasion success (Von Holle and Simberloff 2005). Horticulture is a major anthropogenic pathway, accounting for more than 50% of wildland invaders and 80% of woody invasive species (Reichard 2011).

The human facilitation of English ivy dispersal often occurs through horticultural practices. English ivy is a popular ornamental plant because it is low-maintenance, hardy, and evergreen (Swearingen and Diedrich 2006). According to the NWCB (2001), colonial settlers brought English ivy to the United States in 1727 and to the Pacific Northwest sometime before 1890. Clarke and colleagues (2006) found that regional nursery catalogs between 1915 and 1968 advertised eight common invasive ivy cultivars (Clarke et al. 2006). The Washington State Department of Transportation actively planted English ivy along Interstate 5 (the major north-south corridor) in the 1960s through the 1990s, contributing to its dispersal throughout the western portion of the state (Ray Willard, personal communication 2013). Gardening associations, such as the American Ivy Society, continue to value ivy as a component in English-style gardens. The American Ivy Society's designated "Ivy of the Year" for 2013,

Hedera helix, is invasive to the Pacific Northwest (American Ivy Society, Inc. 2013).

Bioeconomics

The anthropogenic spread of invasive species has economic implications. The Nature Conservancy (2013) estimates global costs of invasive species amount to $1.4 trillion. Pimentel et al. (2005) claim costs to the U.S. economy are around $120 billion. Critics argue that estimates of economic impacts, specifically the calculations of Pimentel et al., conflate calculations of damages and costs, use outdated information, present one-time costs as recurring, and do not consider the potential economic benefits of invasive species (Sagoff 2009). Another method of identifying direct economic costs is to examine invasive species management budgets. The Washington State Department of Transportation spent about $4.5 million in 2011 to combat noxious weeds on its properties (NWCB 2012). The Washington State Legislature allocated $913,173 in the 2009-2011 biennium to support NWCB and Washington State Department of Agriculture invasive species management efforts (NWCB 2012). The Green Cities Partnership, a coalition coordinated by the nonprofit land trust, Forterra, spent about $1.2 million in 2011 on program staff, contracts, and supplies to support volunteer efforts to remove ivy and other invasive species in the cities of Seattle, Tacoma, Redmond, Everett, and Kirkland (K. Kramer, personal communication, May 6, 2013). In addition to monetary costs, the organization estimates volunteer involvement at ivy removal events amounted to 16,000 hours (K. Kramer, personal communication, May 6, 2013).

An emerging field of study, known as bioeconomics, integrates biological factors into economic analyses (Keller et al. 2009). According to Keller and colleagues (2009), the purpose of a bioeconomic model is to "help society design incentive mechanisms that better satisfy political objectives, meet species biological needs, and protect private property concerns". A number of studies utilize bioeconomic models to determine the economic impacts of invasions. McIntosh et al. (2009) describe the importance of considering long-term ecological, economic, and social costs and benefits of a given management response as well as prioritizing limited natural resource funding (McIntosh et al. 2009). For example, managing invasive ornamental species can result in forgone economic benefits to nurseries. The authors also claim policymakers should recognize the opportunity cost of spending public money on invasive species management (McIntosh, et al. 2009). Washington State lawmakers allocate about 1% of the operating budget to natural resource management, only a portion of which is spent on invasive species control (Office of Program Research 2011). The majority of the state's budget goes to education and social services (Office of Program Research 2011). In addition to direct costs and benefits, a bioeconomic model can reflect indirect costs, such as losses of ecosystem services. Cook et al. (2007) estimated that efforts to prevent a varroa bee mite invasion in Australia would likely save the country $27.5 million per year in pollination services (Cook et al. 2007). Bioeconomics often involves complex models that incorporate both direct and indirect costs and benefits of a given policy as well as the opportunity costs.

An impediment to the widespread use of bioeconomic modeling is the lack of quantitative data on the distribution and impacts of individual invaders. Eiswerth and van Kooten (2002) utilized surveys and a stochastic dynamic programming model to identify economically optimal management decisions for yellow starthistle (*Centaurea solstitialis*) in California rangelands. The authors explored expert opinion through surveys of weed scientists, county farm advisors, and public land managers, and subsequently concluded that long-term management of yellow starthistle is the best option (Eiswerth and van Kooten 2002). The survey results coupled with economic modeling effectively addressed the lack of quantitative data on the cost-effectiveness of invasive species management strategies.

There are numerous economic instruments for reducing invasions. One approach is to tax nurseries selling invasive species. Knowler and Barbier (2005) created a model to obtain a social optimum of introductions through an "introducer pays" tax. The model factored in social costs and benefits, plant characteristics, and the number of nurseries (Knowler and Barbier 2005). The authors concluded that a tax may moderately reduce the number of nurseries depending on the invasion risk level acceptable to a given community (Knowler and Barbier 2005). A study by Barbier et al. (2013) surveying horticultural and weed specialist stakeholders revealed an overall preference for mandatory screening and banning of likely invaders over nursery industry fees. The authors determined that nursery industry opposition and uncertainty surrounding invasive species impacts pose implementation challenges for economic policy instruments

(Barbier et al. 2013). In both cases, the viability of taxation as policy option depended on stakeholder values.

In addition to taxes and fees, other potential economic instruments for managing horticultural invaders include import tariffs, tradable permits, graduated license fees, and environmental bonds. The World Trade Organization's (WTO) Sanitary and Phytosanitary Agreement requires countries to assess the likelihood of ecological and economic damage as well as the costs of control prior to implementing import restrictions and tariffs (Powell 2004). A tradable permits system based on invasion risk would be complex, data-heavy, and dependent on heterogeneity among target species (Touza, Dehnen-Schmutz, and Jones 2007). The graduated license fee approach requires higher fees from nurseries contributing greater invasion risk (Touza, Dehnen-Schmutz, and Jones 2007). An environmental bond is a sum based on future projected invasion risk that is charged to nurseries but returned upon demonstrated reductions in invasive species dispersal (Touza, Dehnen-Schmutz, and Jones 2007). These alternative economic policy instruments are not yet widely used and merit further research.

Risk Assessments

Risk assessments can be helpful tools to determine potential invasive species impacts. There are a number of variations on risk assessments that consider different inputs. For example, the Washington Invasive Species Council (2009) utilizes a risk assessment model comparing prevention feasibility to an invader's environmental, economic, and human health impacts (Washington

Invasive Species Council [WISC] 2009). The Council uses the data to calculate an impact score which informs the appropriate management response (WISC 2009). The Council applied its model to 50 priority invasive plant and animal species, but English ivy was not among them (WISC 2009). Various academic studies recommend risk assessments consider climate suitability, habitat availability, points of entry, and propagule pressure (Hulme 2009); incorporate molecular techniques to identify and disrupt introduction pathways (Simberloff et al. 2005); and delineate potential invasion impacts on ecological connectivity (Stohlgren and Jarnevich 2009). Powell (2004) describes the need for a more quantitative approach to risk assessments in order to comply with world trade agreements.

A number of studies identify ways to evaluate risk assessment procedures. Costello et al. (2007) claim the evaluation of an invasive species prevention program must consider the lag time between a species' introduction and its establishment because it may take years for the benefits of prevention measures to materialize. Keller and authors (2007) examine the net economic costs and benefits of Australia's risk assessment protocols with a discount rate of 10-15 years. The authors conclude that the Australian risk assessment program produces net economic benefits, especially long-term (Keller et al. 2007). Risk assessment evaluation over the course of many years can reveal whether prevention measures achieve projected outcomes.

Invasive Species Management

Invasive species management strategies include prevention, eradication, and control. Early detection and prevention are the most cost-effective ways to limit invasive species dispersal. Reichard (2004) explains how horticultural industries could prevent invasions by implementing "voluntary codes of conduct" to curtail invasive plant sales and educate the public. In a prior study, Reichard and White (2001) examine the efficacy of educational outreach as a prevention tool. Through surveys to horticultural customers, the authors found that individuals educated on invasive species are less likely to purchase horticultural invaders (Reichard and White 2001). Holt (2009) describes how practical measures, such as weed-free landscaping products and clean equipment, prevent the spread of invasive species into restoration areas. Quarantines or weed laws are another potential of prevention (Holt 2009). Although prevention measures are often the most cost-effective approach to management, Finnoff et al. (2005) found that risk-averse managers more often choose control over prevention because positive results appear more guaranteed (Finnoff et al. 2005).

Another management option is to remove invasive species once they have become established. If an introduced population is small enough and re-introduction risk is minimal, then eradication is often a cost-effective option, even if initial costs are high (Genovesi 2007). According to Genovesi (2007), eradication is more difficult for flora than fauna because plants have "a dormant life stage, high dispersal capacity, and high reproduction". If the invader is already widespread, resource managers may choose to control it just enough to

maintain agricultural and ecological functions (Holt 2009). Articles by Holt (2009) and Simberloff et al. (2005) describe the utility and drawbacks of control methods. In order to successfully control a species, resource managers should understand its biology and utilize techniques that cause the least ecological disruption (Simberloff et al. 2005). In addition, resource managers must have legal grounds for management, adequate funding, and stakeholder cooperation (Simberloff et al. 2005). Manual or mechanized removal can be an effective but labor-intensive control strategy (Holt 2009). Herbicides are also often effective but are controversial when harmful to non-target organisms (Simberloff et al. 2005). Introducing biological control agents, such as insects that eat the invasive plant, is contentious because the species are often non-native and can have unintended ecological impacts. There are currently no known biological control agents for English ivy (Waggy 2010); manual removal is the most common English Ivy control strategy (personal observation).

In a study of English ivy control methods, Biggerstaff and Beck (2007b) examined the effectiveness of manual removal and herbicide. In some treatment plots, the researchers sowed native seeds after applying removal treatments (Biggerstaff and Beck 2007b). Two months later, Biggerstaff and Beck (2007b) measured the number of germinated seedlings, seedling density, and species richness. The results indicated that pulling ivy allowed for the greatest seedling density and diversity with and without seed addition (Biggerstaff and Beck 2007b). Spraying effectively removed ivy but resulted in lower seedling density and diversity, possibly because the ivy root structure remained intact and inhibited

germination (Biggerstaff and Beck 2007b). In plots where Biggerstaff and Beck left English ivy in place, no seeds germinated (Biggerstaff and Beck 2007b). The authors concluded that hand pulling English ivy and sowing native seeds is the most effective management strategy (Biggerstaff and Beck 2007b).

Removing an invader does not always signify that the habitat will return to its pre-invaded state. Biggerstaff and Beck (2007a) conducted a study investigating restoration potential post-English ivy removal. Specifically, the authors examined seed bank formation and germination (Biggerstaff and Beck 2007a). Research plots included areas where ivy was removed recently or three years prior as well as non-invaded areas (Biggerstaff and Beck 2007a). After monitoring the germination rates and species composition in soil samples over the course of eight months, the authors found that English ivy did not diminish the seed bank (Biggerstaff and Beck 2007a). The authors conclude that restoration involving English ivy removal may succeed due to the paucity of negative residual ecological impacts (Biggerstaff and Beck 2007).

Management Ethics

A moral argument for invasive species control contends that native species have more intrinsic value than non-native species (Boorse 2004). The typical definition of biodiversity in the United States applies only to species and interactions present in North America prior to European settlement (Lodge and Shrader-Frechette 2003). The Columbian benchmark denotes a time when human-facilitated introductions of non-native species increased dramatically

(Lodge and Shrader-Frechette 2003). By distinguishing between anthropogenic and "natural" introductions, proponents of invasive species control imply a separation between humans and nature. Another ethical argument for invasive species control is that certain invaders have negative impacts to public health, the economy, and ecosystem services.

Individuals may morally oppose invasive species management because they believe the introduction of novel organisms is natural and may even benefit ecosystems and society. Some critics argue that anthropogenic introductions are "natural" and the 1492 benchmark is irrelevant (Lodge and Shrader-Frechette 2003). However, Lodge and Shrader-Frechette (2003) argue that assuming humans are part of nature and therefore everything they do is good equates to a "naturalistic fallacy" and undermines the basis of civil society. Sagoff (2009) claims invasive species do not generally lead to the extinction of native species except on island-like habitats. When the spread of an invader does not cause extinction, the introduced organism contributes to the overall species richness of an ecological community and may even provide food or habitat for an endangered species (Sagoff 2009). Once introduced to a new geographic range, an invasive species can increase genetic diversity by diverging from its parent population through mutations, genetic drift, and natural selection (Sagoff 2009). Furthermore, as both native and non-native species assemblages shift due to climate change, invasive species may be more adaptive to environmental change and fill critical ecological niches (Thuiller et al. 2007). Anthropocentric

opponents of control may value invasive species as sources of food, medicine, fiber, biofuel, or ornament.

An additional moral argument against management pertains to harmful control strategies. Certain techniques, such as herbicide or biocontrol, may have unintended consequences that negatively impact biodiversity. According to Evans et al. (2008), exposure to herbicide can backfire if it leads to the natural selection of herbicide-resistant invasive organisms. Killing a species directly or indirectly raises ethical concerns about an individual species' or population's right to life. Opponents would claim that the adverse consequences of management strategies outweigh the benefits of controlling the spread an invader.

There are also ethical dilemmas when management infringes on private property rights. While some may argue that private property autonomy is a "right", Bardach (2012) points out that "…rights are simply convenient tools of social organization and rights-based claims, a consensually accepted way of negotiating the changing landscape of whose interests should be protected to what degree and with what exceptions." It could be argued that the rights of some members of society to house weeds on their properties infringes on the rights of their neighbors to have weed-free properties. In Washington, the state noxious weed board can require private property owners to control certain invaders.

Another moral debacle surrounds the role of scientists. Opponents of scientific involvement in management argue that scientists should maintain objectivity and avoid normative judgments about whether a species is "good" or

"bad" (Lodge and Shrader-Frechette 2003). Some authors argue that terminology, such as "invasive", "alien", and "noxious", is indicative of a xenophobic or nationalistic bias within the scientific community toward non-native species (Evans et al. 2008). Proponents of scientific involvement may claim that science can never truly be objective and the pressing-nature of biological invasions merits a decisive response from the scientific community.

Public involvement in policymaking can also raise ethical questions. Proponents of greater participation assert that public involvement is an expression of democratic ideals. Some believe public behavior is the primary cause of invasive species introductions and is therefore necessary to the solution. Boorse (2004) claims the effects of invasive species are locally-relevant and the public can contribute localized expertise and monitoring. Evans and colleagues (2008) suggest that public participation helps correct management pathologies, such as policies universally eliminating all invaders regardless of impact. In contrast, Bardach (2011) warns that more participation is not necessarily more democratic. He claims people with more time, special interests, and/or ideologies often dominate the participatory process (Bardach 2011). The dilemma with regard to invasive species is that benefits of management are typically diffused while costs are concentrated, so special interests are sometimes the most vocal. Sagoff (2009) poses the dilemma that if invasive species management is meant to be scientific in nature, then stakeholder involvement undermines the scientific process. On the other hand, if invasive species management is political, then scientists should not override the will of stakeholders (Sagoff 2009).

Invasive Species Policy

International, national, and state-level policies address invasive species issues. In the international arena, the United Nations (UN) Convention on Biological Diversity instructs contracting parties to prevent, eradicate, and control invasive species (Convention on Biological Diversity 2013). The Convention garnered 168 signatures between 1992 and 1993 (Convention on Biological Diversity 2013). At the 7th Conference of the Parties, participants recognized horticulture as a key pathway for invasive species introductions (Convention on Biological Diversity 2013). The International Plant Protection Convention (IPPC) is another UN treaty agreement coordinating invasive species management strategies among nations (Clout and De Porter 2005). The World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures ensures invasive species risk assessments do not interfere with free trade (Clout and De Porter 2005).

There are also a number of international invasive species partnerships. The Invasive Species Specialist Group (ISSG), established in 1993, consists of about 170 experts from more than 40 countries (Clout and De Porter 2005). Its mission is to increase awareness about invasive species and offer policy advice to the World Conservation Union (IUCN) (Clout and De Porter 2005). The Global Invasive Species Program (GISP), is a partnership between the IUCN, the Commonwealth Bureau of Agriculture – International (CAB-I), and the UN Environmental Program (UNEP) (United Nations System-Wide Earthwatch 2002). Since its establishment in 1997, the group has published documents on

invasive species management, economics, and legislation (Clout and De Porter 2005). The partnership is currently coordinating a multi-disciplinary working group of experts to encourage international capacity-building and cooperation (Clout and De Porter 2005).

Federal policies pertain to invasive species research, funding, and coordinated management among federal agencies. The United States government created the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) in 1990 to investigate the extent of the invasive species problem and recommend necessary actions (Ielmini et al. 2012). In 1997, the FICMNEW published a plan for federal invasive species response entitled "Pulling Together – A National Strategy for Invasive Plant Management" (Ielmini et al. 2012). President Clinton signed Executive Order 13112 in 1999 establishing the National Invasive Species Council (NISC) to coordinate federal agency programs (Ielmini et al. 2012). Currently, there are 23 federal agencies managing invasive species in some capacity (Simberloff et al. 2005). In 2003, environmental groups formed the National Environmental Coalition on Invasive Species (NECIS) to provide scientific expertise and inform federal policy (Ielmini et al. 2012). The group recently sent President Obama a request for tighter invasive species regulations and additional funding to support research and screening.

Washington State has its own invasive species policies. The legislature established the Washington State Noxious Weed Control Board (NWCB) in 1975 with the intent to "limit economic loss and adverse effects to Washington's

agricultural, natural, and human resources …" (RCW 17.10.007). State weed board members include representatives of county and district weed boards, appointees of the directors of the Washington State Department of Agriculture and the Washington State Association of Counties, and three non-voting scientific advisors (NWCB 2012). The board maintains a weed list designating plants as Class A, B, or C depending on their control requirements and distribution (NWCB 2010b). Class A weeds are new to the area and not widely distributed (NWCB 2010b). State law requires that public and private landowners extirpate Class A weeds on their properties (NWCB 2010b). Class B weeds are widespread in some areas of the state but not others (NWCB 2010b). The board's prioritization strategy is to reduce the abundance of Class B weeds and prevent them from spreading into new areas (NWCB 2010b). Class C weeds are found throughout Washington, and the weed board engages the public in education and outreach on the impacts of those species (NWCB 2010b). County weed boards can opt to require mandatory control for Class B and C species (NWCB 2010b). The NWCB follows rule-making processes to amend the noxious weed list (WAC 17-750). Before adding a species to the list, the NWCB considers public testimony and the plant's economic impact on small businesses.

Public involvement in invasive species policymaking can range from passive forms of participation (i.e. town hall meetings) to active decision-making (i.e. citizen task forces) (Boudejas 2009). Evans and authors (2008) recommend citizen stakeholders and regulating agencies collaborate to develop matrices outlining the pros and cons of managing a particular species. The authors also

advocate for the integration of public input and scientific experimentation, calling the process "experimental pluralism" (Evans et al. 2008). Boorse (2004) notes that although scientists and lands managers have increasingly focused on invasive species in recent years, public awareness has not significantly changed. The author hypothesizes that reasons for low public awareness include a limited public understanding of ecology, a lack of invasive species educational materials, uncertainty and rapid growth within invasion ecology research, and a diversion of public attention to other issues (Boorse 2004). Many authors believe that when the greater public is engaged with invasive species issues, management is more effective.

Future Work

A number of studies in the scientific literature identify future needs for invasive species research. Some authors (Meyerson and Mooney 2007, Chornesky and Randall 2003) argue for more interdisciplinary collaboration to understand and manage invasive species. Chornesky and Randall (2003) suggest developing networked databases to notify officials when an invader expands its distribution. Conservation and management across larger geographic areas would better-protect ecological processes and populations of rare species (Chornesky and Randall, 2003). Long-term research is needed to address the effects of climate change (Chornesky and Randall, 2003, Thuiller et al. 2007). As ecological assemblages change with climate alteration, conservationists may need to reconsider the ecological role of invasive species (Chornesky and Randall 2003, Thuiller et al. 2007). Adopting an interdisciplinary approach and

broadening the spatial and temporal scales of research would greatly expand current knowledge of invasive species issues.

Other knowledge gaps pertain to methodology for analyzing invasive species policies. A major hurdle for policymakers is the lack of quantitative data on the distribution and impacts of individual invaders. Previously mentioned studies use expert opinion surveys to identify economically optimal management strategies for an invasive plant (Eiswerth and van Kooten 2002) or stakeholder preferences for various policies regarding horticultural invaders (Barbier et al. 2013). Combining these methodologies to identify the most effective, cost-effective, and politically feasible policy for a particular invasive species could offer practical information to guide management in a given location. The research presented in Chapter 2 uses expert opinion survey methodology to identify the most favorable and realistic English ivy policy alternatives in Washington State.

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Chapter 2. Analyzing Invasive Species Policies with Expert Opinion Surveys: A Case Study of English Ivy in Washington State

Introduction

Invasive species pose a major threat to biodiversity (Wilcove et al. 1998) and cost the United States billions of dollars each year (Pimentel 2005). Horticulture is a major anthropogenic pathway for invasive species introductions, accounting for more than 50% of wildland invaders and 80% of woody invasive species (Reichard 2011). The dilemma with regard to invasive species policymaking is that public benefits of management are typically diffused while costs are concentrated on certain stakeholders, such as plant nurseries. According to Bardach (2012), "[policy] analysts should… speak up for the taxpayers whose interests may be squeezed out by better-organized advocacy groups." The failure of the market to regulate social and environmental costs of horticultural invaders merits policy intervention. This study offers a framework for analyzing invasive species policy alternatives.

Bardach (2012) proposes that policy analyses define the policy problem, assemble evidence, construct alternatives, select evaluative criteria, project outcomes, and confront trade-offs before deciding on appropriate policy alternatives. Despite some criticisms of invasive species control (see Sagoff 2009), this study assumes that management of certain invaders provides a net benefit to society. The policy problem is therefore the preponderance of non-native horticultural species reproducing without human assistance and causing

negative ecological and economic impacts. Based on a literature review and expert opinion, this study incorporates a framework identifying causes of horticultural invasions and potential policy alternatives (Figure 2.1). Although there are potentially additional invasion influences and policy alternatives, the framework presents common policy themes in invasive species literature. It is important to note that the policy alternatives are not mutually exclusive; policymakers can employ more than one to manage a particular invasive species.

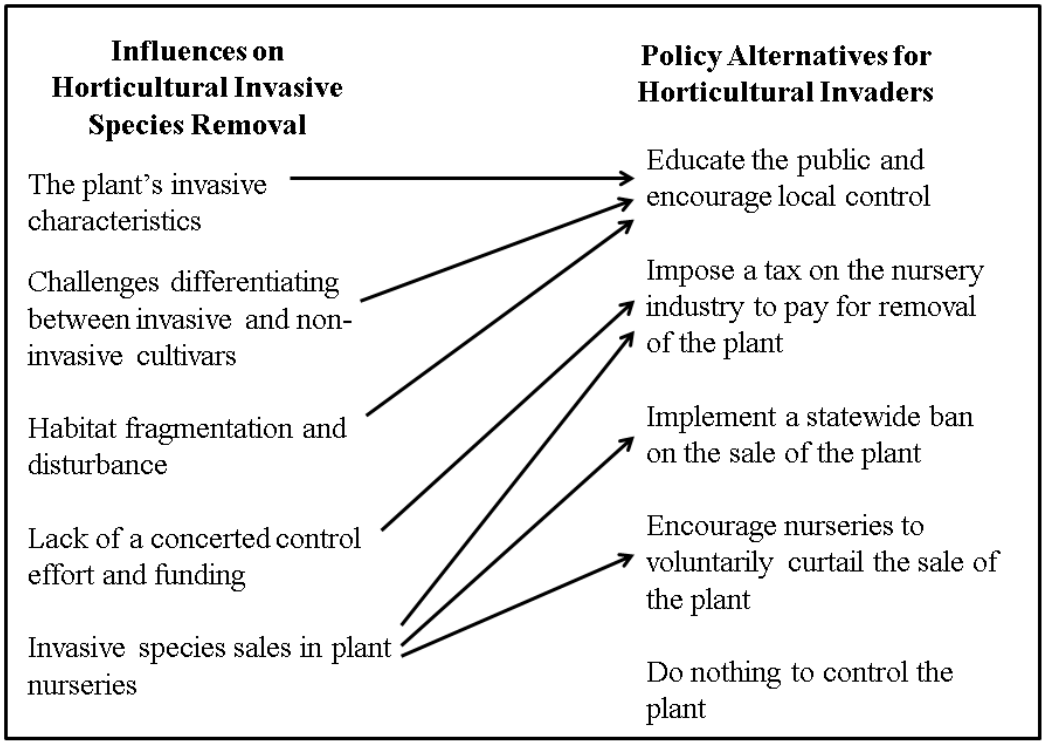

Figure 2.1. Influences on horticultural invasive species dispersal and policy alternatives. Arrows indicate when a policy alternative addresses an influential factor.

Upon identifying the policy problem, the next step in policy analysis is to gather evidence regarding the nature of the problem and possible solutions

(Bardach 2012). A common obstacle to evidence-gathering for invasive species policies is the lack of quantitative data on the distribution and impacts of individual invaders (Eiswerth and van Kooten 2002). Surveys of weed specialists can offer key information in place of quantitative data. Previous studies have utilized surveys to analyze invasive species policy options. For example, Eiswerth and van Kooten (2002) surveyed experts, including weed scientists, public land managers, and others, on the effectiveness of five alternative strategies to control yellow starthistle (*Centaurea solstitalis*) in California. The authors incorporated survey results into a stochastic dynamic programming model to identify economically optimal management decisions (Eiswerth and van Kooten 2002). A study by Barbier and authors (2013) surveyed horticultural industry representatives, hobby gardeners, agriculturalists, park managers and staff, invasive species experts, and conservationists across North America to gauge preferences for bans, taxes, and fees. Both studies utilize surveys to gather information on an invasive species problem and gauge preferences for policy or management alternatives.

In addition to selecting policy alternatives and gathering evidence, another step in the policy analysis process is to establish assessment criteria (Bardach 2012). In this study, there are three criteria: effectiveness, cost-effectiveness, and political feasibility. Effectiveness refers to a policy's ability to limit the future dispersal of an invasive species. Cost-effectiveness pertains to the policy's impact given limited financial resources. While effectiveness and cost-effectiveness are both evaluative, the third criterion is practical; political

feasibility judges whether a proposed policy faces too much opposition or garners too little support (Bardach 2012). The goal of this study is to utilize an expert opinion survey to identify the extent and causes of a specific invasion problem and investigate the effectiveness, cost-effectiveness, and political feasibility of various policy alternatives. The survey specifically addresses the English ivy (*Hedera helix* and *Hedera hibernica*[*]) invasion in Washington State.

English Ivy Characteristics

English ivy is a popular ornamental groundcover invasive to parts of South America, Australia, New Zealand, and 27 states in the United States (Invasive Species Specialist Group 2005). Native to Eurasia, colonial settlers brought English ivy to the United States in 1727 and to the Pacific Northwest sometime before 1890 (Washington State Noxious Weed Control Board [NWCB] 1999). The Washington State Department of Transportation actively planted English ivy along Interstate 5 (a major north-south corridor) from the 1960s through the 1990s, contributing to its dispersal throughout western portions of the state (R. Willard, personal communication, April 3, 2013). Regional nursery catalogs between 1915 and 1968 advertised eight common invasive ivy cultivars (Clarke et al. 2006). Many nurseries in Washington State continue selling invasive ivy.

English ivy occupies a variety of habitat types, but its horticultural origins make it most common in urban landscapes. In Washington State, the Noxious

[*] The common name for *Hedera hibernica* is Irish ivy but many natural resource managers in Washington State refer to all invasive ivy as English ivy.

Weed Control Board describes ivy's habitat preferences as landscaped areas, disturbed forests, fields, hedgerows, and coastal areas (NWCB 2010a). In a review of English ivy research, Waggy (2010) found that English ivy growth rates vary by habitat but tend to increase in moist areas. The Washington State Department of Agriculture distribution map indicates ivy is most common in the temperate areas west of the Cascade Mountain Range (Washington State Department of Agriculture 2011).

English ivy's characteristics contribute to its invasion success. In its juvenile stage, ivy spreads vegetatively (Waggy 2010). The plant uses rhizomes and a sticky substance to climb surfaces in pursuit of sunlight (Waggy 2010). When exposed to sun, its rate of photosynthesis increases and the plant transitions into an adult life involving seed production (Waggy 2010). Dispersers of English ivy seeds include Cedar Waxwings (*Bombycilla cedrorum*), American Robins (*Turdus migratorius*), Stellar Jays (*Cyanocitta stelleri*), Mockingbirds (*Mimus* spp.), European Starlings (*Sturnus vulgaris*), and House Sparrows (*Passer domesticus*) (Swearingen and Diedrich 2006). The glycoside hederin toxin in ivy berries increases the likelihood birds will regurgitate the seeds and facilitate dispersal (National Park Service 2010). English ivy has perfect flowers (Waggy, 2010), and its pollinators are wasps, bees, and flies (Invasive Species Specialist Group 2005). English ivy's characteristics contribute to its competitive advantage over many native plant species.

Another factor contributing to English ivy's invasiveness is genetic plasticity. High propagule pressure of English ivy over time enhanced the plant's

genetic diversity and populations are now more robust. Clarke and colleagues (2006) discerned that English ivy is morphologically variable and individual cultivars can cross with more aggressive ones (Clarke et al. 2006). Based on 58 *Hedera* populations in Oregon, Washington, and British Columbia, the authors discovered the majority of ivy was *H. hibernica* (85%) and the rest was *H. helix* "California", "Pittsburgh", "Star" or other hybrids (Clarke et al. 2006). The authors explain that many invasive English ivy cultivars derived from hybridization and mutation (Clarke et al. 2006).

Invasive ivy has negative environmental and economic impacts. Climbing English ivy, sometimes reaching up to 90 feet, can add considerable weight to trees (Waggy 2010). Ivy can cover up tree leaves and hinder the process of photosynthesis (Swearingen and Diedrich 2006). English ivy can host bacterial leaf scorch (*Xylella fastidiosa)*, a pathogen harmful to many native tree species (Swearingen and Diedrich 2006). Tree stress and death lead to public safety hazards, such as falling trees and branches. Tree losses also reduce arboreal ecosystem services including air purification, stormwater infiltration, and aesthetics. English ivy alters understory habitats through competition. When ivy kills trees and forms an understory monoculture, it is called an "ivy desert" (Okerman 2000). English ivy's displacement of native shrubs likely reduces food and shelter for native fauna.

Methods

Framework and Rationale of Survey Methodology

The methodological process for this study involved identifying the relative importance of English ivy to weed specialists and determining appropriate policy alternatives. Preliminary questions in the web-based survey pertained to the respondent's sector and scope of management. Next, survey respondents indicated English ivy's ranking in their management portfolios as well as the importance of volunteers in their ivy removal efforts. Respondents also identified the relative influence of various factors on the spread of English ivy. The final three questions pertained to the effectiveness, cost-effectiveness, and political feasibility of policy alternatives.

Data Collection

A total of 69 individuals completed the survey in February and March of 2013. Survey participants included state and county weed board program directors and natural resource professionals at state, county, and city levels in both government and nonprofit sectors. In order to reduce redundancy and balance spatial representation, typically only one person from each organization, department, or government program answered the survey. The cities and counties represented in the survey are all within the Puget Sound region. Only cities with large metropolitan areas (populations greater than 40,000) were included based on the assumption that small jurisdictions may not have extensive invasive species programs. Surveys were created and managed through the website SurveyMonkey.com. All responses were anonymous.

The survey contained eight questions. Employment sector options included government, nonprofit, private, and other. Geographic management range choices were state, county, city, or other. For English ivy's ranking in management portfolios, respondents chose from top 5, top 10, top 25, or top 50 species or not a priority. Survey designations of the role of volunteers included very important, important, not important, or not applicable. Factors impacting the spread of English ivy were characterized as having a strong influence, influence, or no influence. For the three policy option questions, participants used a Likert scale to rank a policy's effectiveness, cost-effectiveness, and political feasibility. At the end of the survey, there was a place for respondents to contribute brief comments regarding English ivy policies or the survey design.

Analysis

The main purpose of the analysis was to determine the most appropriate English ivy policy. Favorable responses (agree and somewhat agree) were compared to unfavorable responses (disagree or somewhat disagree) using a Chi-square test. The importance of ivy in management portfolios, the role of volunteers in ivy management, and the influence of various factors on ivy dispersal were examined by comparing responses according to the participants' sectors and management ranges.

Results

English Ivy Importance, Dispersal Factors, and Volunteer Control Efforts

Preliminary questions addressed English ivy's ranking in management portfolios and the role of volunteers in control efforts. A majority of total respondents and nearly all city-level and nonprofit sector respondents considered ivy to be at least among their top 10 species (Table 2.1) and claimed volunteers were important or very important to their English Ivy removal efforts (Table 2.2). In contrast, most state-level participants did not perceive English ivy as a priority (Table 2.1) and 58.3% relied on volunteers (n=12) (Table 2).

The next survey question pertained to the relative influence of various factors on English ivy dispersal. According to respondents, the following factors most strongly influence dispersal: 1) ivy's invasive characteristics; 2) a lack of concerted control efforts and funding; and 3) habitat fragmentation and disturbance (Table 2.3). A higher proportion of state-level and nonprofit respondents perceived ivy sales in plant nurseries as having a strong influence relative to other participant groups (Table 2.3). Few respondents identified challenges differentiating between invasive and non-invasive ivy cultivars as strongly influencing dispersal.

Table 2.1. Responses from natural resource and weed board professionals in Washington State regarding the importance of English ivy in their invasive species management portfolios. "High priority" includes responses indicating English ivy is within the top 5 or 10 species in a management portfolio whereas "low priority" refers to respondent selections of top 25 or 50 species or not a priority.

		High Priority % (N)	Low Priority % (N)
	All Respondents	72.5 (50)	27.5 (19)
Management Range	State	41.7 (5)	58.3 (7)
	County	63.6 (21)	36.4 (12)
	City	100 (18)	0 (0)
Sector			
	Government	61.2 (30)	38.8 (19)
	Non Profit	100 (18)	0 (0)

Table 2.2. Responses from natural resource and weed board professionals in Washington State regarding the importance of volunteers in their English ivy removal efforts.

		Important or Very Important %(N)	Not Important or Not Applicable %(N)
	All Respondents	81.2 (56)	18.8 (13)
Management Range	State	58.3 (7)	41.7 (5)
	County	78.8 (26)	21.2 (7)
	City	100 (18)	0 (0)
Sector			
	Government	75.5 (37)	24.5 (12)
	Non Profit	94.4 (17)	5.6 (1)

Table 2.3. Responses from natural resource and weed board professionals in Washington State regarding factors strongly influencing English ivy dispersal.

		Ivy Traits[1] % (N)	Cultivar Differences[2] % (N)	Habitat Disturbance[3] % (N)	Lack of Control[4] % (N)	Ivy Sales[5] % (N)
	All Respondents	91.2 (62)	3.0 (2)	49.3 (33)	73.1 (49)	37.3 (25)
Management Range	State	90.9 (10)	9.1 (1)	54.5 (6)	54.5 (6)	54.5 (6)
	County	90.9 (30)	3.1 (1)	50.0 (16)	81.3 (26)	28.1 (9)
	City	94.4 (17)	0 (0)	50.0 (9)	66.7 (12)	27.8 (5)
Sector	Government	89.6 (43)	2.1 (1)	46.8 (22)	74.5 (35)	27.7 (13)
	Non Profit	94.4 (17)	5.6 (1)	50.0 (9)	72.2 (13)	61.1 (11)

1. English ivy's invasive characteristics
2. Difficulty differentiating between invasive and noninvasive cultivars of English ivy
3. Habitat Fragmentation and Disturbance
4. Lack of a concerted control effort and funding
5. English ivy sales in plant nurseries.

English Ivy Policy Preferences

Policy 1: Educate the public and encourage weed boards to control English ivy locally

The survey responses indicate that the most effective, cost-effective, and politically feasible English ivy policy is education and localized control (policy 1) (Figures 2-4.). Based on a Chi-square analysis, policy 1 ranked higher than the other policies for each of the three criteria ($p<0.05$) with a few exceptions. A statewide ban (policy 3) was not significantly different from policy 1 with regard

to effectiveness (χ^2=1.52, p=0.22) and cost effectiveness (χ^2=1.69, p=0.19) nor was voluntary curtailment of ivy sales (policy 4) different in terms of and political feasibility (χ^2=1.99, p=0.16). The relationship between policy 1 and policy 4 for cost-effectiveness was on the borderline for statistical significance (χ^2=3.74, p=0.053).

Although policy 1 is somewhat the status quo, participant comments reveal a desire for an increase in current efforts. Some participants believed outreach should come from weed boards while others envisioned nursery industry efforts. One individual identified education as a means to initiate a grassroots movement among community members to remove ivy in backyards, neighborhoods, and local parks. Two survey participants remarked that "educate the public" and "encourage county weed boards to control English ivy locally" are different policies meriting individual consideration. One of those participants noted that he/she supports education, but believes weed boards should only manage species that are not yet widely spread. Another respondent argued that the state weed board should make English ivy a higher priority.

Policy 2: Impose a tax on the nursery industry to pay for English ivy removal

A majority of respondents indicated that a nursery tax (policy 2) may not be a realistic policy strategy at this time, in large part due to perceptions of political feasibility. Although the most common response regarding the political feasibility of policy 2 was "somewhat disagree", respondents most often somewhat agreed with its potential effectiveness and cost-effectiveness (Figures

2.2-2.4.). Two respondents commented that a tax would be divisive and unlikely to garner legislative support. Many participants remarked on the need for more financial resources for English ivy control but did not necessarily support a tax. One commenter suggested that utilities contribute to management efforts because ivy threatens overhead wires.

Policy 3: Implement a statewide ban on English ivy cultivars

The implementation of a statewide English ivy ban (policy 3) invoked mixed results. As previously mentioned, agreement with the effectiveness and cost-effectiveness of policy 3 was not statistically different from policy 1. The most common responses were "agree" for effectiveness and cost-effectiveness but "somewhat disagree" for political feasibility (Figures 2.2-2.44). One survey participant hoped the Washington State Department of Agriculture (WSDA) would add four invasive ivy cultivars to the quarantine list whereas another person did not envision legislative support for a ban. A third participant noted that ivy sales from big box stores were only one of many factors contributing to its spread.

Policy 4: Encourage nurseries to voluntarily curtail the sale of English ivy

Respondents indicated that the voluntary curtailment of English ivy sales (policy 4) is a favorable policy option. Respondents most often agreed with the effectiveness and cost-effectiveness of policy 4 (Figures 2.2-2.3). However, the most common response for political feasibility was "somewhat agree" and the proportion of favorable responses was significantly lower than for policy 1

(χ^2=1.99, p<0.16) (Figure 2.4). One respondent noted that the Pacific Northwest Invasive Plant Council plans to implement a Nursery Certification Program for retailers curtailing English ivy sales once funding is available.

Policy 5: Do nothing to control English ivy

The option to do nothing to control English ivy (policy 5) was highly unpopular. The most common response for the effectiveness, cost-effectiveness, and political feasibility of policy 5 was "disagree" (Figures 2.2.-2.4). Some survey comments indicated that it is too late for control efforts because English ivy is widespread and the available seed source is large. One person remarked that many ivy-infested areas are inaccessible for management (i.e. private property).

EFFECTIVENESS

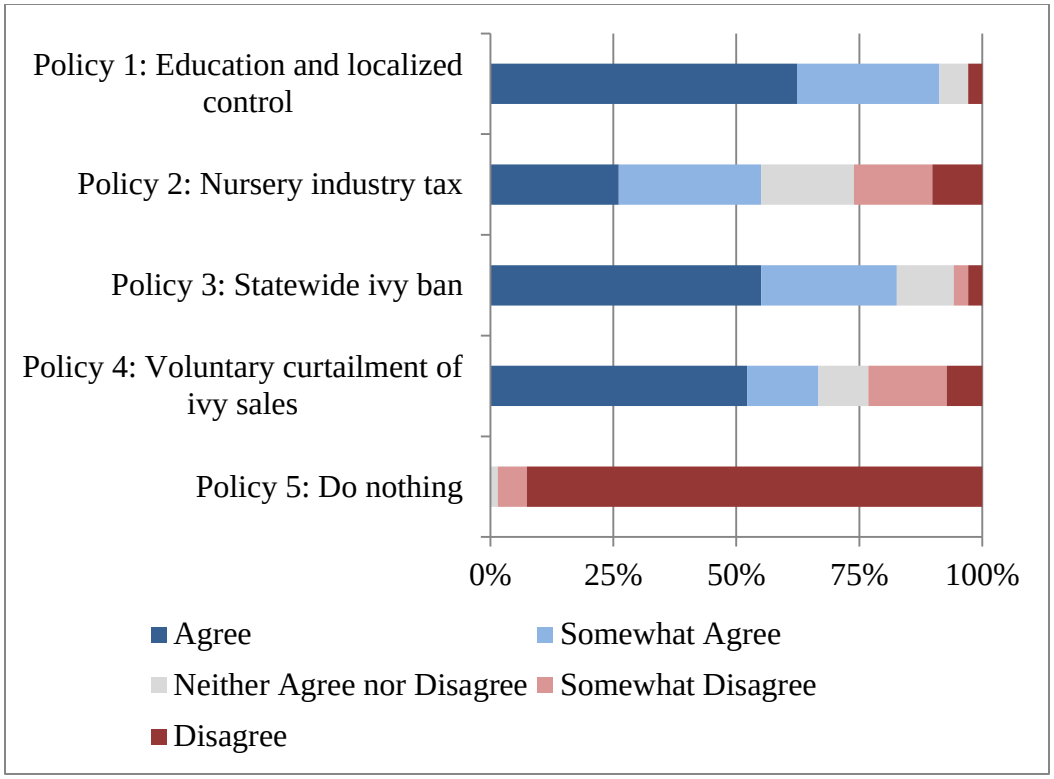

Figure 2.2. Responses from natural resource and weed board professionals in Washington State regarding the effectiveness of policy alternatives for English ivy management.

COST-EFFECTIVENESS

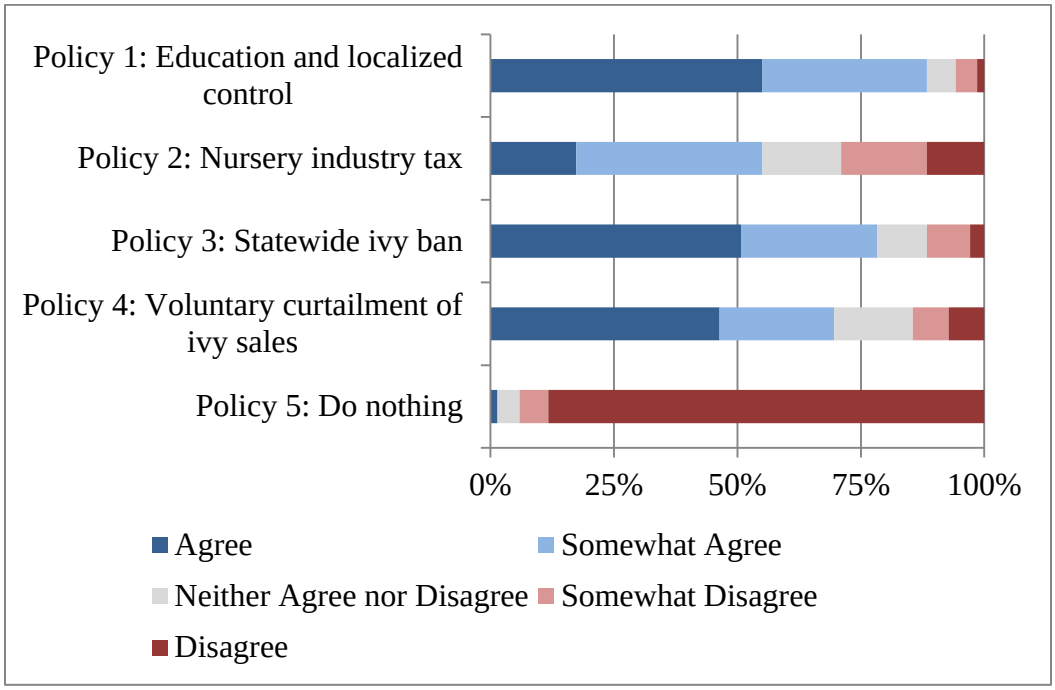

Figure 2.3. Responses from natural resource and weed board professionals in Washington State regarding the cost-effectiveness of policy alternatives for English ivy management.

POLITICAL FEASIBILITY

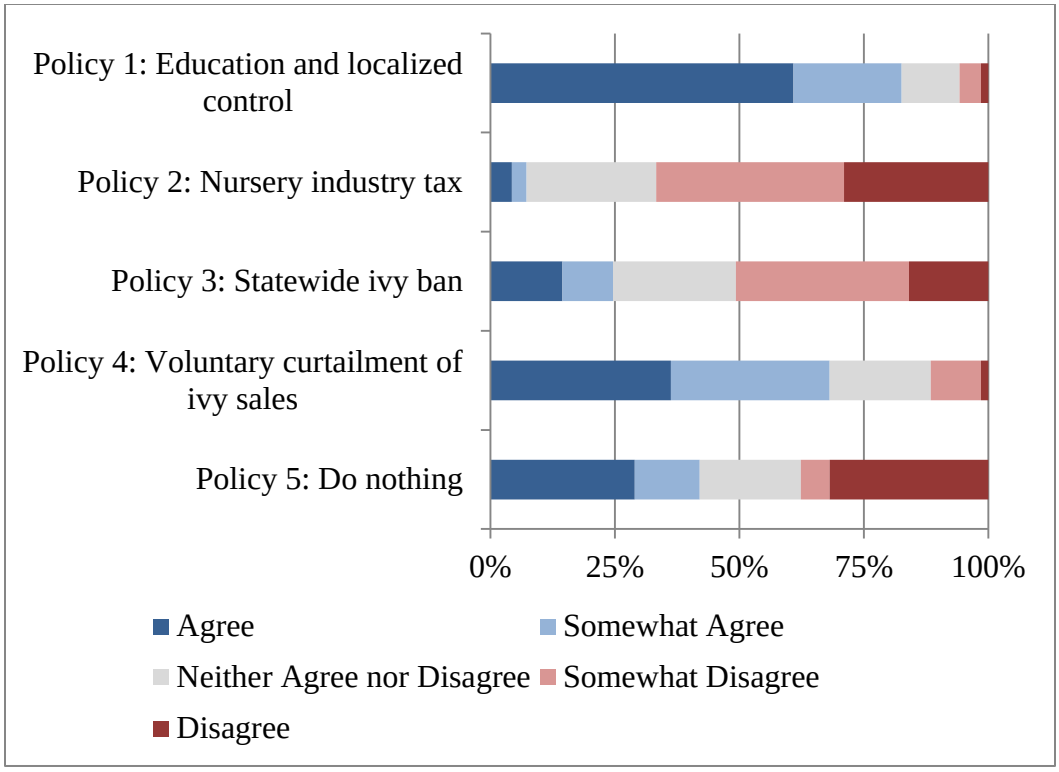

Figure 2.4. Responses from natural resource and weed board professionals in Washington State regarding the political feasibility of policy alternatives for English ivy management.

Discussion

Discussion of Results

The overall preference for education and localized control of English ivy (policy 1) reflects current practices in Washington State. The Washington State Noxious Weed Control Board (NWCB) maintains a weed list designating plants as Class A, B, or C depending on their control requirements and distribution (NWCB 2010b). Class A weeds are new to the area and not widely distributed (NWCB 2010b). State law requires that public and private landowners extirpate Class A weeds on their properties (NWCB 2010b). Class B weeds are widespread in certain areas of the state (NWCB 2010b). The board's prioritization strategy is to reduce the abundance of Class B weeds and prevent them from spreading into new areas (NWCB 2010b). Class C weeds are found throughout Washington, and the weed board engages the public in education and outreach on the impacts of those species (NWCB 2010b). County weed boards can opt to require mandatory control for Class B and C species (NWCB 2010b). In 2002, the Washington State Noxious Weed Control Board (NWCB) added four English ivy cultivars to the state noxious weed list as Class C (NWCB 2010a).

There was some opposition to English ivy's Class C listing during the NWCB's public comment period. A few individuals argued ivy should be a higher priority (Class A or B species) and added to the state's quarantine list (English ivy testimony, personal communication, 2002). Others claimed English ivy's benefits outweigh environmental costs and more attention should instead be paid to invaders like Scotch Broom (*Cytisus scoparius*) and Himalayan blackberry

(*Rubus armeniacus*) (English ivy testimony, personal communication, 2002). Despite some expressions of concern, the vast majority of letters sent to the NWCB expressed support for adding English ivy to the noxious weed list.

Although the Class C listing permits localized control and education, efforts have been relatively limited. No county weed board currently requires private landowners to remove English ivy. The City of Tacoma did pass a nuisance ordinance in 2007 prohibiting "unkempt" and "uncultivated" vegetation. Many cities also conduct their own English ivy maintenance and partner with nonprofit organizations to coordinate volunteer control efforts. Since English ivy's noxious weed listing in 2002, the NWCB has included the plant in its "Garden Wise" publication, recommending garden alternatives such as crinkle-leaf creeper (*Rubus pentalobus*), kinnikinnik (*Arctostaphylos uva-ursi*), or climbing hydrangea (*Hydrangea anomala subsp. petiolaris*). Survey participants in this study indicated that localized control and education efforts in western Washington should increase.

It is not surprising that a tax on the nursery industry (policy 2) was an unpopular option. A study by Barbier and authors (2013) determined that nursery industry opposition and uncertainty surrounding invasive species impacts pose implementation challenges for economic policy instruments. In a survey of horticultural and weed specialist stakeholders, the authors found that a nursery industry fee was particularly unpopular. Furthermore, Washington State residents regularly oppose new taxes. In 2007, Washington voters passed an initiative (I-960) requiring a two-thirds majority approval in the legislature for tax or fee

increases. The state legislature repealed the decision in 2010 but voters passed another version in November of that year (I-1053). Even though the state Supreme Court has since declared unconstitutional subsequent attempts at tax restrictions (including I-1185), the anti-tax message from voters is clear. The current political environment in Washington would likely not support policy 2.

Variation among responses regarding a statewide English ivy ban (policy 3) may reflect participant knowledge of policy precedent in other states. Of the states recently attempting to ban English ivy sales, two failed (Virginia, Maryland) and one succeeded (Oregon). While not all varieties of English ivy are invasive, Oregon's statewide ban applies to all varieties (Scigliano 2012). The implementation of a Washington state ban of English ivy would require the Washington State Department of Agriculture (WSDA) to add the species to its quarantine list (WAC 16-752-600 through 690). The WSDA evaluates the costs and benefits of any proposed changes to the list as well as impacts to stakeholder groups. Currently, there are 64 terrestrial plants on Washington's quarantine list, all of which are either Class A or Class B noxious weeds (Washington State Department of Agriculture 2010). Inspectors are already overwhelmed: there are only eleven WSDA employees in charge of inspecting 6,500 licensed nurseries for quarantined plants as well as all timber and hay exports for insects (T. Wessels, personal communication, May 17, 2013). A statewide ban of English ivy sales would not impact horticultural imports from Canada (Tom Wessels, personal communication, 2013). Without a comprehensive risk assessment, the World Trade Organization (WTO) views international quarantine as arbitrary

barriers to trade (Powell, 2004). Limited resources and the complicated political nature of statewide bans pose potential barriers to policy 3.

General agreement among respondents in favor of voluntary measures (policy 4) reflects actions occurring to a certain extent in Washington State and elsewhere. In 2006, the Washington State Nursery and Landscape Association (WSNLA) endorsed a "voluntary code of conduct" to reduce invasive species introductions and educate the public on the impacts of invasions (Center for Plant Conservation 2013). Since then, the WSNLA has included information on invasive species in its trade magazine and collaborated with the NWCB on educational materials (Center for Plant Conservation 2013). The Washington State Native Plant Society's "IvyO.U.T" website has its own list of ten nurseries in Washington pledging to curtail English ivy sales (Washington Native Plant Society 2012). Touza and authors (2007) assert that the success of voluntary codes of conduct depends on the extent of their promotion among industry professionals and the public. With greater promotion of current efforts, policy 4 may be a viable option but perhaps less effective than policy 1.

The vast majority of respondents rejected the "do nothing" option (policy 5); similarly, most studies acknowledge that invasive species require management. The few academics opposing management argue that human introduction of native organisms is natural because humans are part of nature. Lodge and Shrader-Frechette (2003) claim that assuming everything humans do is "natural" and therefore "good" is a "naturalistic fallacy" and undermines the basis of civil society. Management opponents also decry reports of economic and

ecological impacts as exaggerated. Some academics believe scientists should not subjectively determine whether a species is "good" or "bad" (Lodge and Shrader-Frechette, 2003). The counter argument would be that science can never truly be objective and the pressing-nature of biological invasions merits a decisive response from the scientific community. Stakeholders and the academic community overwhelmingly object to policy 5.

Discussion of Methods

One of the strengths of this study was the high response rate. According to Muňoz-Leiva and authors (2010), typical response rates for electronic surveys in the early years of email were approximately 50%, and they have continued dropping ever since. However, personalized phone calls and emails to participants prior to the survey may account for the high response rate in this study (92%).

This study also has some limitations. First, the policy alternatives are general and not exhaustive. The survey did not specify the details of each policy (i.e. the rate at which a nursery would be taxed) nor did it elaborate on the logistics of implementation and enforcement. Other policies that merit future consideration include the implementation of environmental bonds, tariffs and graduated license fees; the conservation of large tracts of habitat; and the requirement of English ivy removal on private and public property. The purpose of a general approach is to assess which types of policies are most favorable so

that a follow-up study can address particular components of the top one or two policies.

Second, weed board and natural resource professionals are only one type of stakeholder involved in invasive species issues. Nursery industry professionals and the gardening public also have a stake in English ivy dispersal. Surveys to weed specialists are intended as a preliminary step in policymaking, and other stakeholders should participate in the decision-making process as well. Although initial studies can focus on expert opinions, wide-ranging stakeholder buy-in further along in the process is often helpful for successful policy implementation.

Third, survey questions relied on assumptions about the survey participant's prior knowledge. The choice of assessment criteria assumed respondents had a familiarity with the costs and effectiveness of each policy alternative as well as Washington's political climate. Political scientists coined the term "bounded rationality" to describe how the decisions of experts are confined by limited information, resources, and human cognition (Clark 2002, Fiorino 1995). Limits to expert knowledge may have constrained survey responses and the subsequent formation of generalized conclusions about English ivy polices.

Fourth, there are drawbacks to survey methodology. Weed specialists tend to work in the field most days and may not regularly check email. Also, the target respondent universe is more difficult to control for an anonymous web-based survey. For example, one respondent forwarded the survey on to a few

other people, which may have confounded the target survey universe slightly. In addition, there may have been some variation in the respondents' interpretation of different agreement levels. Despite some logistical shortcomings, the electronic survey method is an efficient and inexpensive means of gathering expert opinion.

Future Work

Various modifications or additions to this study could contribute to knowledge about survey methodology and English ivy policy alternatives. The next step in pursuing the most appropriate statewide efforts could be to conduct a focus group or follow-up survey regarding cost and implementation strategies specific to the most favorable policy option(s) (i.e. policies 1, 3, and/or 4). In addition, policymakers should set target outcomes (i.e. acreage of restored habitat) and evaluate the effectiveness and cost-effectiveness of the chosen policy strategy once enacted. Economic analyses of policies should include ecosystem services. The input of other stakeholders in the decision-making process can anticipate potential political feasibility problems and encourage buy-in. Follow-up studies, broad economic analyses, and increased stakeholder involvement could all add to this study's conclusions.

Conclusion

Analysis is warranted for invasive species policies because management typically contributes to the greater public good. Expert opinion surveys can serve as a cost-effective and user-friendly solution to the lack of quantitative data for a particular invader in the evaluation of policy alternatives. Weed board and

natural resource professionals in participating in this study most often favored the policy alternative regarding education and localized control efforts (policy 1) with regard to effectiveness, cost-effectiveness, and political feasibility. The second most highly favored policy option was voluntary curtailment of English ivy sales in nurseries (policy 4). Although results for cost-effectiveness and political feasibility were similar between policies 1 and 4, the proportion of favorable responses for the effectiveness of policy 4 was significantly lower than for policy 1 (χ^2=13.48, $p<0.001$). Future research could utilize focus groups or follow-up surveys to explore the rationale for policy preferences as well as establish implementation details for the most favorable policy.

Appendices

Table 2.4. Responses from natural resource and weed board professionals regarding the effectiveness of statewide policy alternatives in limiting the spread of English ivy in Washington State.

	Agree or Somewhat Agree % (N)	Disagree or Somewhat Disagree % (N)
Educate the public and encourage county weed boards to control English Ivy locally	71.7 (43)	2.9 (2)
Impose a tax on the nursery industry to pay for English Ivy removal	55.1 (38)	26.1 (18)
Implement a statewide ban on the sale of English Ivy cultivars	82.6 (57)	5.8 (4)
Encourage nurseries to voluntarily curtail the sale of English Ivy	66.7 (46)	23.2 (16)
Do nothing to control English Ivy	0 (0)	98.5 (66)

Table 2.5. Responses from natural resource and weed board professionals regarding the cost-effectiveness of statewide policy alternatives in limiting the spread of English ivy in Washington State.

	Agree or Somewhat Agree % (N)	Disagree or Somewhat Disagree % (N)
Educate the public and encourage county weed boards to control English Ivy locally	88.4 (61)	5.8 (4)
Impose a tax on the nursery industry to pay for English Ivy removal	55.1 (38)	29.0 (20)
Implement a statewide ban on the sale of English Ivy cultivars	78.3 (54)	1.3 (9)
Encourage nurseries to voluntarily curtail the sale of English Ivy	69.6 (48)	14.5 (10)
Do nothing to control English Ivy	1.5 (1)	94.1 (64)

Table 2.6. Responses from natural resource and weed board professionals regarding the political feasibility of statewide policy alternatives in limiting the spread of English ivy in Washington State.

	Agree or Somewhat Agree % (N)	Disagree or Somewhat Disagree % (N)
Educate the public and encourage county weed boards to control English Ivy locally	82.6 (57)	5.8 (4)
Impose a tax on the nursery industry to pay for English Ivy removal	7.2 (5)	66.7 (46)
Implement a statewide ban on the sale of English Ivy cultivars	24.6 (17)	50.7 (35)
Encourage nurseries to voluntarily curtail the sale of English Ivy	68.1 (47)	11.6 (8)
Do nothing to control English Ivy	42.0 (29)	37.7 (26)

Table 2.7. The most common responses from natural resource and weed board professionals regarding the effectiveness, cost-effectiveness, and political feasibility of policy alternatives for English ivy management as well as Chi-square comparisons with the most popular policy (Policy 1).

		Policy 1: Education & Local Control[1]	Policy 2: Tax on Nurseries[2]	Policy 3: Statewide Ban[3]	Policy 4: Voluntary Measures[4]	Policy 5: Do Nothing[5]
Effectiveness	Most common Likert scale response	Agree	Somewhat Agree	Agree	Agree	Disagree
	Significantly different from policy 1?	N/A	Yes (χ^2=18.42, df=1, p<0.001)	No (χ^2=1.52, df=1, p=0.22)	Yes (χ^2=13.48, df=1, p<0.001)	Yes (χ^2=123.23, df=1, p<0.001)
Cost-Effectiveness	Most common Likert scale response	Agree	Somewhat Agree	Agree	Agree	Disagree
	Significantly different from policy 1?	N/A	Yes (χ^2=15.66, df=1, p<0.001)	No (χ^2=1.69, df=1, p=0.19)	No (χ^2=3.74, df=1, p=0.053)	Yes (χ^2=111.01, df=1, p<0.001)
Political Feasibility	Most common Likert scale response	Agree	Somewhat Disagree	Somewhat Disagree	Somewhat Agree	Disagree
	Significantly different from policy 1?	N/A	Yes (χ^2=78.63, df=1, p<0.001)	Yes (χ^2=45.84, df=1, p<0.001)	No (χ^2=1.99, df=1, p=0.16)	Yes (χ^2=30.29, df=1, p<0.001)

1. Policy 1: Educate the public and encourage county weed boards to control English ivy locally
2. Policy 2: Impose a tax on the nursery industry to pay for English ivy removal
3. Policy 3: Implement a statewide ban on the sale of English ivy cultivars
4. Policy 4: Encourage nurseries to voluntarily curtail to the sale of English ivy
5. Policy 5: Do nothing to control English ivy

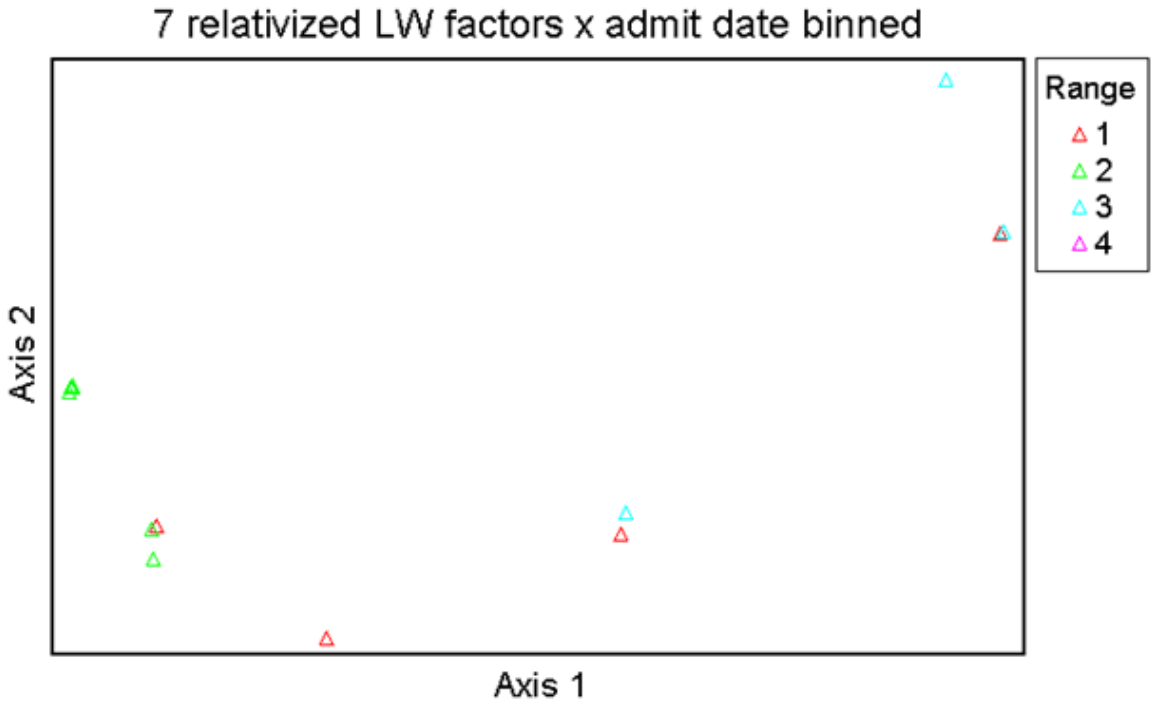

Figure 2.8 Ordination comparing survey responses of natural resource and weed board professionals regarding English ivy's relative importance in management porftolios (top 5, top 10, top 25, top 50, or not a priority) according to geographic management range (state=1, county=2, city=3, other=4) (A=0167, $p<0.001$).

Survey Questions

1. In which sector do you work?

- ○ Government
- ○ Nonprofit
- ○ Private

Other (please specify)

2. In which geographic range do you manage for invasive species?

- ○ State
- ○ County
- ○ City

Other (please specify)

3. Where does English Ivy rank in your management portfolio of invasive species?

- ○ Top 5 Species
- ○ Top 10 Species
- ○ Top 25 Species
- ○ Top 50 Species
- ○ Not a Priority

4. How important are volunteers to your organization's English Ivy removal efforts?

- ○ Very Important
- ○ Important
- ○ Not Important
- ○ Not Applicable

5. Please rank the following according to their influence on the spread of English Ivy:

	Strong Influence	Influence	No Influence
English Ivy's invasive characteristics	○	○	○
Difficulty differentiating between invasive and noninvasive cultivars of English Ivy	○	○	○
Habitat fragmentation and disturbance	○	○	○
Lack of a concerted control effort and funding	○	○	○
English Ivy sales in plant nurseries	○	○	○

6. The next three questions separately address the effectiveness, affordability, and political feasibility of potential statewide English Ivy policies.

Please identify if the following policy options would effectively limit the future spread of English Ivy:

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
Educate the public and encourage county weed boards to control English Ivy locally	○	○	○	○	○
Impose a tax on the nursery industry to pay for English Ivy removal	○	○	○	○	○
Implement a statewide ban on the sale of English Ivy cultivars	○	○	○	○	○
Encourage nurseries to voluntarily curtail the sale of English Ivy	○	○	○	○	○
Do nothing	○	○	○	○	○

7. Please identify if the following policy options would be cost-effective management tools for English Ivy:

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
Educate the public and encourage county weed boards to control English Ivy locally	○	○	○	○	○
Impose a tax on the nursery industry to pay for English Ivy removal	○	○	○	○	○
Implement a statewide ban on the sale of English Ivy cultivars	○	○	○	○	○
Encourage nurseries to voluntarily curtail the sale of English Ivy	○	○	○	○	○
Do nothing to control English Ivy	○	○	○	○	○

8. Please identify if the following policy options would likely receive support from the state legislature:

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
Educate the public and encourage county weed boards to control English Ivy locally	○	○	○	○	○
Impose a tax on the nursery industry to pay for English Ivy removal	○	○	○	○	○
Implement a statewide ban on the sale of English Ivy cultivars	○	○	○	○	○
Encourage nurseries to voluntarily curtail the sale of English Ivy	○	○	○	○	○
Do nothing	○	○	○	○	○

9. Please note below any additional comments or ideas you may have regarding English Ivy policies in Washington State.

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3. Research Significance and Future Directions

Research Significance

My thesis explored invasive species policy analysis from an interdisciplinary perspective. Chapter One reviewed the academic literature pertaining to major themes in invasive species research. With regard to invasion ecology, researchers have examined the characteristics intrinsic to invasive species and invaded habitats. A number of studies have identified the anthropogenic drivers of invasive species dispersal, including horticulture. Researchers have developed bioeconomic models to calculate the costs associated with particular invaders and have analyzed the ability of economic instruments to limit future invasions. Studies on risk assessments have incorporated various factors in the evaluation of invasion risk for a given species or pathway. Restoration biology research has investigated the efficacy of various prevention, eradication, and control strategies. In response to a growing concern regarding the ecological and economic impacts of invasive species, governments and nongovernmental organizations have collaborated on policies to manage invaders at the international, federal, state, and local levels.

Chapter Two presented the results of my investigation of expert opinion survey utility in identifying favorable and realistic policies for an invasive plant species. Web-based surveys are an inexpensive and efficient means of gathering data on the management priorities and policy preferences of expert stakeholders, despite the unlikelihood of including all policy alternatives and reaching every stakeholder. I surveyed natural resource and weed board professionals to

determine the most effective, cost-effective, and politically-feasible management strategy for English ivy, an invasive plant in Washington State. My survey results indicated that respondents perceive English ivy as a priority species in the Puget Sound region and prefer education and localized management as a policy approach. Although the policy preference reflects current practices in Washington State, participant comments revealed a desire for enhanced efforts.

Future Directions for Invasive Species Research and Management

As demonstrated in Chapter One of this thesis, diverse disciplines, such as invasion ecology, restoration ecology, population biology, geography, economics, political science, and philosophy, all address invasive species issues in some way. Chornesky and Randall (2003) suggest that greater interdisciplinary collaboration would contribute to better understanding and management of invasive species. It is also necessary that individual researchers have some foundation of knowledge in areas outside their primary disciplines. For example, it would be helpful for scientists to understand the political process in order to guide the formulation of research questions that are relevant to policymaking and management.

Chornesky and Randall (2003) also recommend future research focused on the potential impact of global climate change on the invasion process. Changes in temperature and precipitation will likely alter the distribution of both native and invasive species. Invaders tend to be highly adaptive and may gain an even further competitive advantage in the advent of climate change (Chornesky & Randall 2003). As an invasive species in both Oregon and California, English ivy would likely continue invading habitats in Washington if temperatures increased.

English ivy has demonstrated phenotypic plasticity which contributes to its overall ability to adapt to environmental change. Research on English ivy's likely response to climate change would help inform future statewide management policies.

Future studies should explore policy analysis options. My thesis addresses general policy alternatives for a specific invader. A follow-up survey or a focus group could identify implementation details and elucidate the reasons behind stakeholder preferences. Follow-up questions for the English ivy survey participants could focus on specific information regarding the preference for education and localized control efforts including the content of educational materials, target management goals, stakeholder responsibility for administering education and leading control efforts, and funding sources. Understanding the reasons why respondents opposed certain policies would also be beneficial. The English ivy survey respondents did not perceive a statewide ban as a politically feasible policy option even though Oregon recently implemented one. A follow-up study could identify whether respondents are aware of the Oregon ban, if they view Oregon's ban as ineffective, or if they believe the Washington political environment is different.

Species-specific economic studies would also enhance the policy analysis process. Research on a particular invader's impact on ecosystem services would help define the policy problem and inform the selection of policy alternatives. English ivy impacts tree survival and germination which in turn reduces arboreal ecosystem services. Future studies could investigate English ivy's influence on

other ecosystem services, such as erosion control and water infiltration. English ivy's public health impact as a common habitat for rats is another important consideration. Research on the economic importance of English ivy to the nursery industry and the viability alternative groundcover plants would indicate if voluntary curtailment of ivy sales among nurseries is a reasonable expectation.

Lastly, incorporating expert opinion surveys into policy analyses can substitute for the lack of quantitative data on a number of plant and animal invaders. The flexibility and efficiency of web-based survey methodology could make data collection on any type of invasive species virtually instantaneous at very little cost. The formulation of an invasive species survey template and database could inform policies at the local, regional, or even global level.

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