ON THE WILLINGNESS-TO-PAY FOR ELODEA REMOVAL IN THE FAIRBANKS NORTH STAR BOROUGH

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Abstract

The empirical research conducted herein addresses a public need for the funding of a project that would eradicate Elodea in the Fairbanks North Star Borough (FNSB). The eradication project has been outlined and approved by State and Federal agencies and has gathered funding to begin the eradication process. The study aims to develop a mean willingness-to-pay value for survey participants by shifting the funding burden to property tax payers. This body of work includes a primer on Elodea in the borough, an overview of contingent valuation, a parametric approach to willingness-to-pay, and results of the study conducted on Fairbanks property owners.

The average willingness-to-pay per survey respondent is $50.32. In addition, 72% of survey respondents voted for the enactment of the program at their proposed cost level. These financial burdens took values of $10, $30, $60, or $120 per year for 4 years to fund the proposed program. A penalized maximum log-likelihood estimation found that the most significant predictors for the likelihood of a yes vote are the respondent's perceived risk to the ecosystem and recreational opportunities. Additionally, the respondents concern for the use of herbicides in the borough to treat the Elodea infestation is highly significant. The high level of prior knowledge throughout the survey indicates that respondents had established view on Elodea prior to the survey.

Table of Contents

Page

List of Figures

Page

List of Tables

Page

Introduction

An invasive sub-aquatic plant species known as Elodea was discovered in 2010 in the interior of Alaska. This discovery amplified the search for the invasive plant throughout the state and pulled invasive species management into focus. Elodea is a common invasive throughout North America and has been determined native by most of the southern Canadian territories and most U.S. states. Prior to this discovery, Alaska had limited exposure to invasive species due to geographic location.

Eradication in the Fairbanks North Star Borough (FNSB) is beginning in the summer of 2018. State and Federal authorities have authorized the use of an aquatic herbicide known as Fluridone in the interior. Aquatic herbicides offer the highest rate of success at the lowest cost. Additionally, these herbicides have been used successfully throughout southcentral Alaska. Funding is a constant source of concern for invasive species management in Alaska. Eradication funds come from a combination of Federal, State, and private ecosystem protection groups. With shifting environmental focuses, funding for invasive management is neglected. Allocated funds to begin the eradication process include a single year of funding. This project requires subsequent years of funding to reapply herbicides in prevention of a re-infestation. Success of this project relies heavily on the availability of funding.

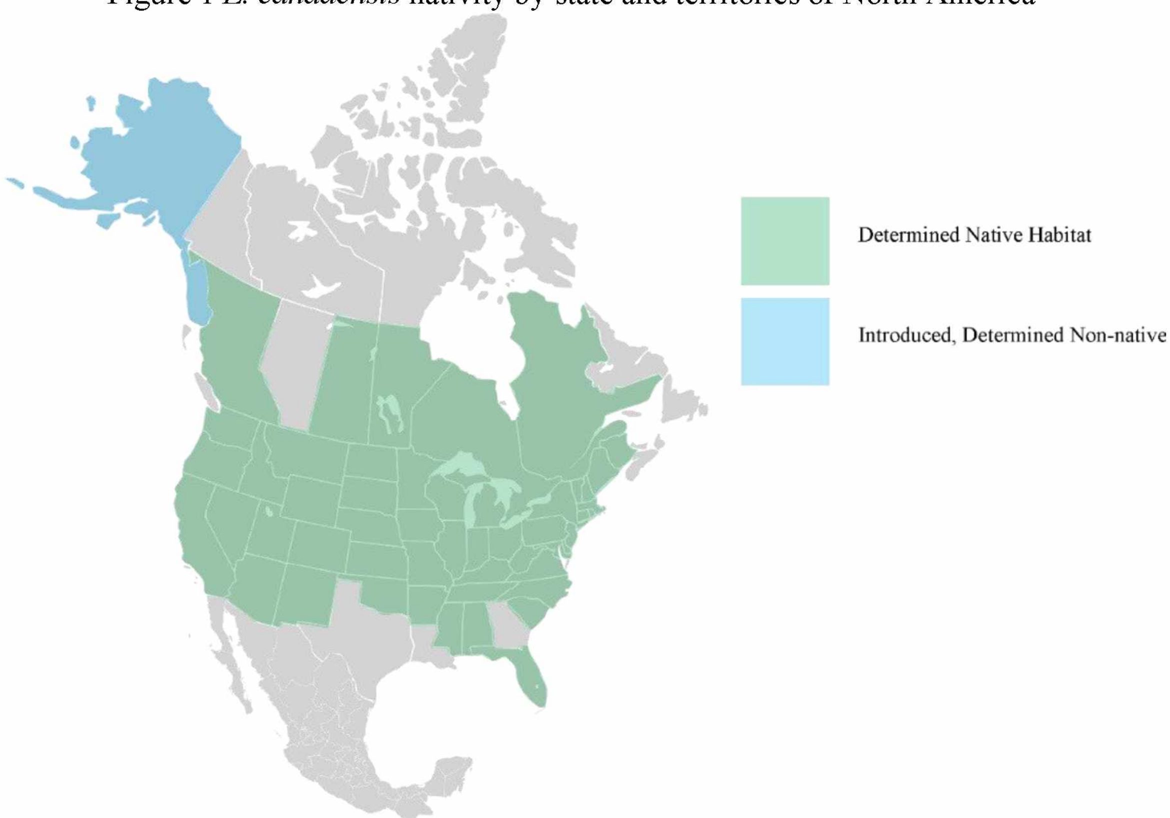
This body of work aims to introduce readers to Elodea, its risks, treatment, and the infestation in the FNSB. Then follows an overview on contingent valuation (CV). This is the approached used in the empirical study to elicit an average respondents dollar value for a proposed ecosystem protection program. A parametric approach is detailed and finally the empirical study and results are presented.

An Elodea Primer for the Fairbanks North Star Borough

What is Elodea?

Elodea is a subaquatic plant species found in the United States, Europe, Asia, Africa, New Zealand, and Australia (Carey, Sethi, Larsen, & Rich, 2016). The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) currently lists 5 species of Elodea in the U.S.; bifoliata, callitrichoides, canadensis, nuttallii, and schweinitzii. The only species of Elodea in Alaska is canadensis, also known as the Canadian Waterweed. Research has been conducted to determine that *E. canadensis* is not native and was introduced through recreation (Wurtz, Lisuzzo, Batten, & Larsen, 2013). The following map indicates the North American region in which Elodea canadensis is native, as determined by the USDA (figure 1).

Figure 1 *E. canadensis* nativity by state and territories of North America



The interior infestation of Elodea brings significant attention to potential ecosystem risks and it's ability to spread aggressively; to date there are 22 known infestations throughout the state of Alaska. Most of the infestations occur in the eastern maritime climatic region and south central (Division of Agriculture, 2017). While the interior has the least amount of infestations, the potential to spread is of considerable concern. Luizza et al. (2016) found that the interior is home to hundreds of thousands of potential waterways that exhibit a perfect environment for Elodea to flourish.

The risks of an Elodea infestation can be devastating, so much so, that five states have banned the sale and/or ownership of any variation of Elodea.[1] The aggressive rate of spread and its difficulty to remove make Elodea a nuisance to public and private waterbodies. Elodea can regrow from its own stem fragments making physical removal inadequate. Proliferation is aided by the ability to grow under the ice and survive being frozen (Sainty & Jacobs, 1981). It also withstands long distance travel, strong current conditions, and flourishes in toxic water conditions (Barrat-Segretain, Elger, Sagnes, & Puijalon, 2002).

Natural and Recreational Impacts of Elodea Infestations

There is a direct correlation between the health of a waterbody, the ecosystem in which it is a part, and recreational opportunity. Elodea has an aggressive rate of expansion that includes both spread and density that outcompetes native aquatic species. These attributes cause damage to the waterway by slowing the stream velocity, increasing sedimentation rates, and altering the availability of nutrients (Buscemi, 1958; Pokorný, Květ, Ondok, Toul, & Ostrý, 1984)

In the interior, Elodea infects anadromous waterways. The Tanana River Management Area (TRMA) includes spawning grounds for Alaska King, Chinook, and Chum Salmon. Non-salmon species include Arctic Grayling, Humpback Whitefish, Burbot, Northern Pike, and many others. An Elodea presence creates prime habitat for Northern Pike to hunt and spawn creating artificial advantages for any predator-prey interactions. Merz et al. (2008) found Elodea to directly compete with Chinook salmon habitat due to spread and density. An Elodea presence has created introduced competition that will directly affect subsistence users. The Totchaket Slough, an infested waterway within the interior, is the only infested waterway with a primary

[1] States in which Elodea is illegal are Alabama, New Hampshire, New York, South Carolina, and Washington.

use being designated as subsistence harvest. Potential damages to this habitat would impact these users and other wildlife that use the slough (Division of Agriculture, 2017).

It is natural that when fish and river health conditions deteriorate, so do recreation opportunities. The lower half of the Chena slough is currently experiencing over 50% coverage by Elodea (Division of Agriculture, 2017). A study by Southwick Associates et al. (2008) estimates a decrease of 1% of the salmon sport fishing opportunity would cost $140 million throughout the state and $980,000 in the interior over the course of per year. It is unknown how detrimental the current infestation has been to sport fishing opportunities. Another study by Zhang and Boyle (2010) found Elodea to foul boat propellers, render waterways impassible, and decrease property values. The Chena Lakes Recreation Area (over 50% Elodea coverage at some test sites) is a manmade recreation site designed to provide the FNSB with non-motorized boating, fishing, and other lake recreation opportunities. It is clear to see how Elodea can hinder wildlife and recreation opportunity across the State and the interior.

Treatment Options

Control options for Elodea have been extensively researched and eradication efforts have been successful as a result. Eradication in Alaska is contingent on State and Federal approval of an environmental assessment of the impacts to the economy and ecosystem. These assessments include in-depth analysis on possible control options for the area. The information in this subsection is largely gathered from the 2017 Interior Alaska Elodea Eradication Project Environmental Assessment.

Elodea invasion amplifies with the time of presence. For every year that Elodea is present, the cost of removal increases. There are three main removal options; mechanical, engineering, and herbicidal. Mechanical (physical) options involve laborious techniques such as hand pulling Elodea from the roots, shredding, and the use of underwater suction dredges. Engineering options involve physical alterations to the waterbody to assist in the removal of Elodea. Examples of engineering options include creating strategic drainages, altering the water levels, and creating manmade barriers. The goal of these alterations is to effect the behavior of the water and make it less hospitable for Elodea to proliferate.

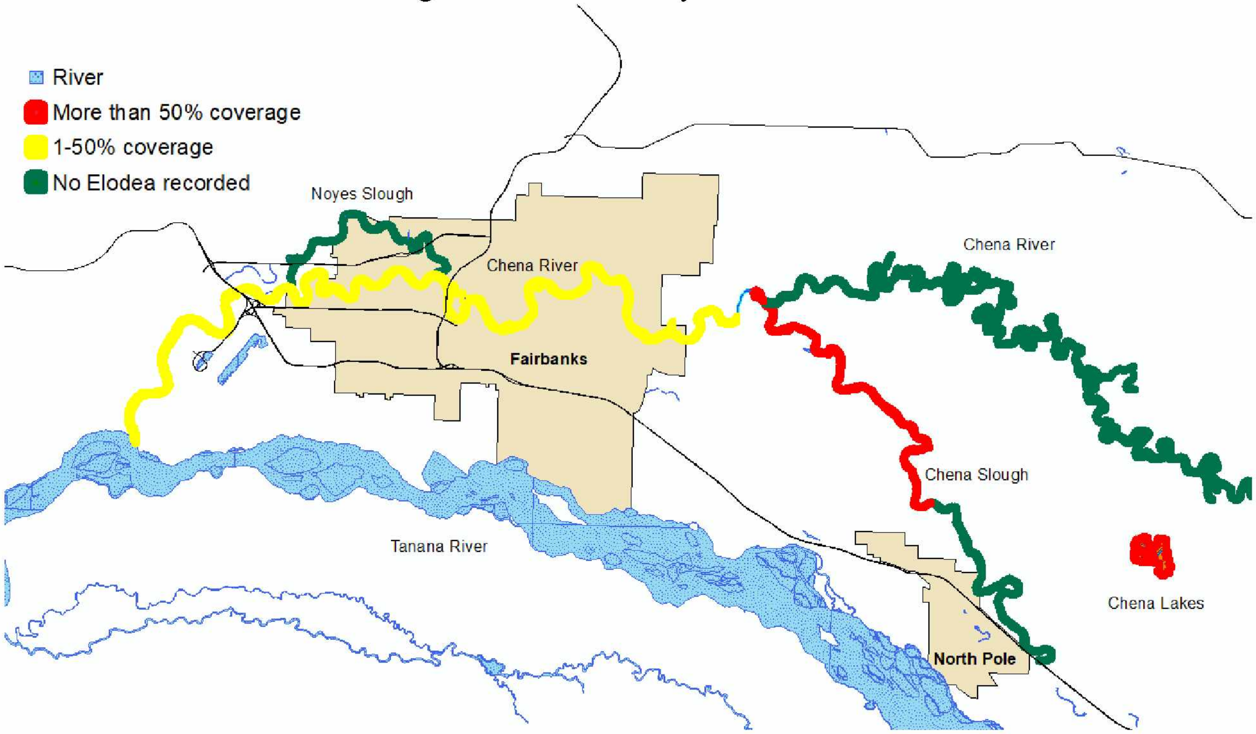
Chemical control options are the most widely used in the Alaska. Options include the use of Fluridone, Diquat, and Chelated-Copper Compounds. These options benefit low-flow areas such as ponds, lakes, and sloughs. The most beneficial trait of chemical control is the low costs per acre and success rates. One analysis found that Fluridone treatments could cost between $118 and $783 per acre (Division of Agriculture, 2017). Complete eradication requires 45-90 days of treatment time for two or more growing seasons. Public concern for the use of aquatic herbicides is common but the Environmental Protection Agency (EPA) has approved the use of Fluridone in waters that have direct contact with humans and wildlife without having negative effects (Division of Agriculture, 2017).

Other forms of removal exist such as the introduction of aquatic species that consume Elodea (biological control), adjusting the pH level of the water, and others. Most of these control options are experimental and/or do not contribute to the overall conservation of the ecosystem.

Elodea Eradication Project in the Interior

In 2013, the DNR quarantine process classified Elodea as invasive to Alaska, thus requiring DNR oversight in removal and prevention. Through regimented site testing, Elodea was found in the Chena Slough, Chena Lake, Totchaket Slough, and small portions of the Chena River (see figure 2).

Figure 2 Elodea density in the FNSB



Adapted from a FBSWCD graphic (Totchaket Slough not pictured)

The most egregious infestations were found in the Chena and Totchaket Sloughs due to their density and distribution potential (Division of Agriculture, 2017). As previously stated, Elodea is primarily spread using recreational equipment such as boats, paddles, fishing gear, etc. Each of the infected waterways in the interior have high recreational value. Risk potential is high due to infested waterways and their tributaries flowing into major rivers such as the Tanana and Yukon. Lane et al. (2013) tested the effectiveness of mechanical (physical) removal options on a 1-acre plot of Elodea in the FNSB. Mechanical removal was found to be cost ineffective, laborious, and increased the infestation after the growing season. The proposed and approved treatment for eradication is the use of an aquatic herbicide known as Fluridone (sold under the name of Sonar Genesis™, Sonar One™, and SonarH4C™). To date, there are 3 other approved environmental assessments in Alaska that use Fluridone to treat Elodea. Fluridone use does not affect water quality parameters such as pH, color, hardness, dissolved oxygen, and turbidity (McCowen, Young, & West, 1979). In addition, the EPA as well as the Alaska Department of Environmental Conservation (DEC) have approved the use of Fluridone to treat invasive species with proper application. Fluridone is removed from the waterbody through microbial degradation and solar energy. One study found that Fluridone has a half-life of 20 days in pond water and up to 3 months in soil (West, Burger, Poole, & Mowrey, 1983). Fluridone also does not have much potential to invade ground water since it naturally binds to soil matter, traveling the first few inches of underwater soil at a maximum (Muir, Grift, Blouw, & Lockhart, 1980). The application of Fluridone is expected to have a negative short-term impact on native vegetation but is expected to quickly rebound with long-term benefits being much greater (Division of Agriculture, 2017). The use of this aquatic herbicide can return waterways to pre-infestation levels. The application of Fluridone is not expected to have any chronic or acute effects on wildlife. Testing of mammals, birds, humans, fish, and other non-vegetative species found Fluridone to be safe when used in instructed amounts (Division of Agriculture, 2017).

The current eradication effort lacks the funding required to complete the entire project. It is expected that eradication in the Totchaket Slough and Chena lake to take 2-3 years and 2-4 years for the Chena Slough. The Fairbanks Soil and Water Conservation District (FSWCD) is tasked with eradication efforts. Preliminary funding has been acquired for eradication activities to begin in the Chena and Totchaket Slough through the Alaska Sustainable Salmon Fund and the United States Fish and Wildlife Service (USFWS). The overall project to remove Elodea from the Chena Lake, Chena Slough, and Totchaket Slough is estimated to cost approximately $1.5 million.

Contingent valuation (CV) can be used as a means to measure the value of Elodea removal to borough residents. The infestation of *E. canadensis* in the interior presents ecological, economic, and recreational risks. Perceived risks such as environmental damage, decreases in recreation opportunities, and existence values of native fish populations all can be used to elicit the value of the project to residents.

Literature Review

Introduction to Contingent Valuation

Historical maximizations of public benefit were limited to what is priced by traditional demand and supply markets. When it comes to natural resources, economists found it difficult to valuate non-market goods such as the value of clean air, the right to clean water, accessibility to recreation opportunities, and existence goods. As a result, economists developed contingent valuation methods. This approach can help determine whether public actions such as the decision to allocate resources towards non-market goods are beneficial and by how much (Haab & McConnell, 2003).

A Brief History on Contingent Valuation

There are two dominate schools of thought when valuing public goods, behavioral and stated preference. The behavioral approach measures how public goods effect the behavior of an individual; even more revealing are their changes in behavior given a change in the public good. The stated preference method in which researchers pose structured hypothetical questions in which respondents are required to make decisions between fluctuations in public resources (decrease in air quality, the damming of a river, opening of a coal mine, etc.) and how much they would be willing to pay (WTP) or accept (WTA) for those changes. From these responses, one can comment on the value of a public good. This method of stated preferences is called contingent valuation (CV) since the WTA/WTP for the public good is contingent on the information provided to the respondent (Hoyos & Mariel, 2010).

The CV method was developed within the United States during the 1950's as a way to determine willingness-to-pay for outdoor recreational opportunities. The US National Parks Service was intent on estimating a monetary value of a visit to national parks (Davis, 1963). The first known CV approach was produced by Davis to place an economic value on recreation in Maine through the use of a bidding game. The surveyor would increase or decrease the cost of a public good until the respondent changed their response (more on this later). Given that the proposed program would cost the respondent some amount of money, this would allow the surveyor to approximate the maximum WTP for that program. During early estimations of public goods, recreational value was measured primarily with travel cost methods. Davis' use of this contingent valuation method was compared with a travel cost method of the same recreation site and found results that were not statistically different (Knetsch & Davis, 1966). Due to the convergent validity of the results, other researchers found interest and began implementing their own CV studies. The approach became particularly useful when underlying costs, such as the value of clean air, was thought to be a determining factor in a respondents decision process. This is difficult to measure with traditional hedonistic models, so CV was first used in a study of air pollution in Philadelphia and Syracuse (Ridker & Henning, 1967). Throughout the years following Davis' study, many economists used the CV method to study recreation values. Everything from the value of hunting, lower congestion on hiking trails, amenities at urban parks, and the water quality at Boston beaches (G. M. Brown & Hammack, 1974; Cicchetti & Smith, 1973; Hanemann, 1978).

CV methods began to gather considerable Federal attention. The 1979 revision of the Water Resources Council's planning policy required that federal projects include recommended economic valuation methods, of which CV surveys were a viable option (Mitchell & Carson, 1989). Additionally, the passing of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 allowed for the recovery of lost value when estimated using CV methods (Portney, 1994). The traction gained by CV methods was so considerable that in 1983, the EPA commissioned a state-of-the-art study to determine the legitimacy of CV methods in measuring the value of environmental resources. The resulting body of work described a high level of potential and that like any new methodology, kinks needed to be worked out (Carson et al., 1998).

Arguably, the most pivotal moment came from an oil spill. The Exxon Valdez oil spill occurred off the shores of Valdez, Alaska. This dramatic spill caused damage to the shoreline as well as the Alaskan fishing and tourism industry. The State of Alaska proceeded to sue Exxon for the value of the damages that it caused. It was one of the first cases in which the compensation amount was determined with aspects of CV. The oil industry had an uproar and began a marketing campaign slandering the use of CV methods of not being reliable and producing unrealistic estimates (Diamond & Hausman, 1994). Government response was needed to rectify backlash, so it was determined that if the Federal government were to base its decisions off CV analysis, that there should be guidelines that are followed in order to produce trustworthy valuations. In 1993, the National Oceanic and Atmospheric Administration (NOAA) Blue Ribbon Panel developed a set of guidelines and strategies in the formulation of questions and information to produce realistic results. Since the valuation is contingent on the information presented to the respondent, it was paramount that the information and formulation of questions were unbiased and easy to understand. In addition, this panel determined from an extensive literature review of past CV research, that CV methods were able to produce reliable enough results to help guide administrative and judicial decision-making.

Modern CV research (2000 to present) has mostly focused on the underlying economic theory and statistical framework of CV studies. Approaches to CV methods are constantly being proven and disproven. It is safe to say, that in its current stage, CV methodology is constantly changing for the better, while remaining a reliable source of information in valuing environmental and intrinsic goods.

Willingness-to-Pay vs. Willingness-to-Accept

In measuring pareto improvements, there are two commonly used formats. The WTP format asks the respondent how much they are willing to pay to see a change in public goods. The WTA format asks the respondent how much currency they are willing to accept for a change in public goods. The goal for both formats is to monetize the value of potential pareto improvements, though often, WTA and WTP results arrive at different conclusions. The reasons for such are mostly theoretical and root themselves in how the respondent perceives the hypothetical scenario. The most common misuse of WTP analysis is when it is applied to a WTA scenario (Bromley, 1995). For example, when the proposed hypothetical scenario presents a resource loss, then WTA should be used (T. C. Brown & Gregory, 1999). A multitude of studies have been conducted pre-2000 testing the disparity between WTP and WTA responses.[2] The explanations for these discrepancies amount to various income effects, transaction costs, implied value, and profit motives with a slew of other effects and motives (T. C. Brown & Gregory,

[2] For a brief list of literature on this topic, visit Table 1 from T. C. Brown & Gregory, 1999.

1999). The overall take away is that individuals simply respond differently to gains and losses, hinting at the notion that individuals are risk adverse, contrary to neo-classical economic framework. This study employs the WTP framework as the questionnaire presents the creation of a borough-funded program. Since this program represents an environmental improvement, the use of a WTP approach is appropriate (Bromley, 1995).

Convergent Validity for Hypothetical Dichotomous Choice Formats

Convergent validity for WTP studies use tests to determine statistical significance between actual and stated WTP amounts. These studies pose hypothetical dichotomous choice questions that elicit WTP and compare them to the same study conducted with actual WTP. These test are known throughout literature as external tests of validity. Framework studies such as Kealy, Dovidio, and Rockel (1988), Champ et al. (1994), and Loomis et al. (1997) find that stated and actual WTP values were statistically different. More current literature suggests that while there remains to be overestimation present in stated WTP values, certain steps can be taken to minimize or even reduce this hypothetical bias (T. C. Brown, Ajzen, & Hrubes, 2003; Loomis, 2014; Ryan, Mentzakis, Jareinpituk, & Cairns, 2017). Loomis (2014) suggests the use of an *ex ante* and *ex post* approach. *Ex ante* approaches are steps taken before the WTP question is elicited. These methods include revisiting the consequentiality of the response, using cheap talk scripts to warn the respondent of hypothetical bias, and to urge respondent to respond as if they had to pay at the moment of the survey (Loomis, 2014). A common e*x post* approach introduces a certainty scale after the WTP elicitation. Respondents who recorded high levels of certainty in their response generally had no statistical difference between their stated and actual WTP (see Loomis (2014) for a table of literature regarding certainty scales and criterion validity). With the use of hypothetical bias reduction methods, stated WTP can be considered appropriate in estimating actual WTP values.

Willingness-to-Pay Elicitation Methods

Since the WTP format is optimal for this survey topic, eliciting the respondents most accurate payment threshold becomes a topic of its own. Elicitation formats fall into one of the following general formats: single question, and multi-question. The single question format contains open-ended responses, payment cards, and referendum style questions. The multi-question format most generally contains bidding games and choice-based conjoint analysis. This section will provide a brief overview of each as well as justification towards the use of a referendum style question in the Elodea survey.

Open-ended questions are a form of single question formats and were a popular debate topic in early survey designs. Modern CV literature suggests that open-ended response formats are particularly unreliable. One study compared the results of all different types of elicitation formats for WTP and found that open-ended responses contributed to the lowest WTP and the highest variance (Ahmed & Gotoh, 2006). Respondents find it difficult to place a value on something when they are not given a reference point. This contributes to a high variance in the knowledge of respondents, producing untrustworthy results. An example of this question format is as follows:

> Elodea coverage is supposed to increase in both density and coverage next summer. The proposed program would create a fund to eradicate Elodea. Keeping in mind your budget, how much would you be willing to pay if the program were to pass? (WRITE 0 IF NONE)

This makes it difficult for the respondent as they do not have a point of reference to make an educated decision. The respondent is then more likely to respond strategically to avoid overpaying. Another strategic decision the respondent could make is to pay close to nothing, under the impression that someone else who cares more will pay more. This is the fundamental bases of the free-rider theory.

There is also the bidding game elicitation method. The benefit of this method is that it enables the researcher to find maximum WTP and minimum WTA for goods (Mitchell & Carson, 1989). The downside of this is that the starting value of the choice experiment seems to imply a value for the good, potentially making results biased. This auction style game consists of dichotomous choice format as noted above where the interviewer will ask the question repeatedly at higher or lower levels of cost until the respondent changes their answer. This will allow the interviewer to collect a "tipping point" or maximum willingness-to-pay for the program. The most common argument against bidding games is that the starting bid from a researcher establishes a value for the program in the respondents mind, severely altering the respondents answers (Mitchell & Carson, 1989).

Another common approach is to use a payment card method, designed by Mitchell and Carson in 1981. This method presents a series of costs to the respondent who is then tasked with selecting their desired level. An example of a payment card is shown below.

How much would you be willing to pay for this program? (CIRCLE ONE OPTION)

$0	$5	$15	$50
$100	$200		

The problem surrounding payment card methods are the same as bidding games. They provide a range of topics that are determined by the researcher and present uncertainty in the value of the program. Interestingly enough, one study on WTP for public parks in Nagasaki, Japan found that the payment card method almost negated the discrepancy between WTA and WTP values (Ahmed & Gotoh, 2006).

The FNSB Elodea survey employed a referenda style single question format. The goal of this format is to mimic a real-world scenario that is both familiar to the respondent and includes incentive compatibility. This is typically the most popular form of WTP elicitation. The question is in the form of a ballot measure, where the enactment of a proposed program would require the respondent take on an additional cost. The question used in this empirical study on Elodea is as follows:

If the program to get rid of Elodea in the FNSB were to happen, and it would cost you $___ per year for 4 years (total of $___), would you vote for the program? (PLEASE CIRCLE ONE)

YES NO WOULD NOT VOTE

There are many advantages to using a referendum model for a CV study. The most important advantage is the familiarity and appropriateness of using referendums to pay for public goods. In the real world, many public resource allocations are determined by ballot measure. When a local government is unsure of the most appropriate use of funds, a ballot measure can be proposed to determine the allocation most beneficial to the public. This makes referendums the most realistic and familiar since it is more than likely that the respondent has voted before.

In order for survey estimates to truly elicit a respondent's intentions, incentive compatibility requirements must be met. Incentive compatibility is the notion that a good survey will invoke the respondent to feel that there may be some sort of follow-up to their response. In order to focus this discussion, only binary choice surveys will be covered as it is the elicitation format used in this thesis. The referenda style of question previously stated is an example of binary choice (though a third option is invoked to more realistically represent the sample). If a respondent is asked to take on the burden of an additional cost for a yes vote, it is important that the vote is made under the assumption that if the program is enacted, they will be required to pay said amount. Though this would never happen from a survey of the nature (since WTP surveys would gather a mean WTP to be charged to citizens), it removes certain bias such as the strategic response bias.[3] The binary choice format was recommended by the NOAA Blue Ribbon Panel as the best format for contingent valuation (Arrow et al., 1993). Additionally, articles by Gibbard (1973) and Satterthwaite (1975) claim than any other response format that contains more than two choices is not incentive compatible (e.g. the payment card). Carson and Groves (2007) conduct a thorough and systemic literature review on the use of binary choice formats and conclude that binary choice formats with coercive payment structures are completely incentive compatible when correctly posed.[4] It is from a large body of supporting literature that the binary choice format is an appropriate format to ensure incentive compatibility.

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[3] The strategic response bias is the notion that a respondent will vote yes to a program regardless to the proposed cost level so that the program passes. This is usually done by extremist representatives and the respondent has no intention to contribute the amount or already contributes more than the proposed amount and would like others to by enacting the program.

[4] An example of a coercive payment mechanism would be the use of taxes if the program were to pass. In addition, Carson and Groves (2007) concluded that voluntary payment mechanisms were not incentive compatible due to the ability for the respondent to choose to not follow up on their commitment.

A Parametric Approach to Referendum Based Willingness-To-Pay

Introduction

The decision to use WTP calculations for this data set were determined by a small literature review on different approaches and their variance in resulting estimations. Many WTP estimations exists, some of the most common include the logit, probit, and the mixed logit. Many other econometricians have proposed their own methodologies in calculating mean WTP. The Sieve method is a rendition of a probit model that allows for distribution-free heteroskedasticity, most recently expanded in 2007 (Chen, 2007). Mean WTP has also been found by modeling it as a survival function (Watanabe, 2010). Depending on the type of approach used, WTP estimations can vary greatly. Traditional parametric approaches like the logit and probit models have been found to return higher results than survival methods (Satimanon & Lupi, 2011). Regardless of this variation, a traditional parametric approach known as the logit model will be used to determine WTP estimates. This approach builds off a linearized random utility model, penalized maximum log-likelihood estimations, and then finally, WTP calculations.

Random Utility Model

Dichotomous choice surveys are characterized by the presentation on whether a respondent would accept or pay some fixed amount of money by responding yes or no. McFadden first developed the framework for the random utility model (RUM) through a series of publications that laid the groundwork for dichotomous choice econometrics (McFadden, 1976). From this framework, Hanemann developed the most basic form of estimation with dichotomous choice responses (Hanemann, 1984). In contingent valuations regarding dichotomous choice surveys, two possible indirect utility variations can occur.

$$v_{in} = v_i(y_n, \boldsymbol{x_n}, \varepsilon_{in}) \tag{1.1}$$

In equation 1.1, the i subscript shows their response to the dichotomous choice question. If the subscript is 0, then the respondent voted no (status quo). If the subscript is 1, the respondent voted for the program to pass. To properly capture a cost burden on an individual, their discretionary income must be recorded, y_n. The indirect utility of the n^{th} respondent is determined by their bundle of characteristics.[5] Where $\boldsymbol{x_n}$ is an m-dimensional vector containing characteristics determined by auxiliary survey questions such as age, gender, prior knowledge of the topic, etc.[6] In addition, ε_{in} is included to represent all preferences known only to the survey respondent. In order to build off of equation 1.1, an assumption of ceteris paribus must be made between a yes vote and a no vote and assume that the difference between the two is an unknown measurable parameter known from herein as ϑ^i. From this revelation, two possible indirect utility statements are created. For example, if the respondent voted yes, the following statement to be true.

$$v_1(y_n, \boldsymbol{x_n}, \vartheta^1, \varepsilon_{1n}) > v_0(y_n, \boldsymbol{x_n}, \vartheta^0, \varepsilon_{0n}) \tag{1.2}$$

As mentioned before, in order to catch the burden of the fixed cost level presented to the respondent, it must be incorporated as following with the value of c_n – the cost level presented to the respondent. The following equation represents a respondent's higher utility by voting for the program given a cost of c_n.

$$v_1(y_n - c_n, \boldsymbol{x_n}, \vartheta^1, \varepsilon_{1n}) > v_0(y_n - c_n, \boldsymbol{x_n}, \vartheta^0, \varepsilon_{0n}) \tag{1.3}$$

Since these statements contain error terms that are unknown to the estimator, inference is limited to a respondent's probability of responding yes to a program given known factors. From this assumption, equation 1.3 is converted into the following probability statement.

$$Pr(YES_n) = Pr\Big(\big(v_1(y_n - c_n, \boldsymbol{x_n}, \varepsilon_{1n})\big) > \big(v_0(y_n - c_n, \boldsymbol{x_n}, \varepsilon_{0n})\big)\Big) \tag{1.4}$$

Equation 1.4 is a statement that the probability of a respondent voting yes is dependent on their collection of discretionary income, matrix of survey responses, unknown quality indicator, and their collection of unobservable preferences; that their overall utility will be increased even with subtracting the overall cost of the program from their discretionary income. To continue analysis on survey responses, the respondent's indirect utility function must be further broken

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[5] The term characteristics and preferences is used interchangeably throughout this document. Each refers to an individual's responses to the questionnaire that are not the dichotomous choice section (E.g. age, gender, prior knowledge of Elodea, etc.).

[6] Bold-faced parameters in this paper are matrix notation. An example of this vector is $\boldsymbol{x_n} = \begin{bmatrix} \alpha_0 \\ \alpha_1 \\ \dots \end{bmatrix}$

down into an additive statement of known and unknown parameters. Equation 1.4 is then rewritten into the following.

$$v_i(y_n, \boldsymbol{x_n}, \varepsilon_{in}) = v_i(y_n, \boldsymbol{x_n}) + \varepsilon_{in} \tag{1.5}$$

$$Pr(YES_n) = Pr\left(\left(v_1(y_n - c_n, \boldsymbol{x_n}) + \varepsilon_{1n}\right)\right) > \left(v_0(y_n - c_n, \boldsymbol{x_n}) + \varepsilon_{0n}\right)\Big) \tag{1.6}$$

Since both ε_{in} and ε_{0n} are both random components, they can be combined into the single random parameter of $\varepsilon_n \equiv \varepsilon_{in} - \varepsilon_{0n}$. From this statement, the final derivation needed to perform parametric analysis can be completed. Define the CDF as $F_\varepsilon(a) = Pr(a > \varepsilon)$, then the following equation reveals the final form necessary where a equals the probability statements from equation 1.6 rewritten into the following form.

$$\Pr(YES_n) = 1 - F_\varepsilon\left(-\left(v_1(y_n - c_n, \boldsymbol{x_n}) - (y_n, \boldsymbol{x_n})\right)\right) \tag{1.7}$$

Penalized Log Likelihood Maximization for Dichotomous Choice Data

It is imperative to use multiple approaches in the final WTP estimation. In this thesis, two parametric approaches are used. The probit and logit approaches often return similar results, but their estimation procedures are slightly different. The framework explained in this subchapter is largely based off of the work of Haab and McConnell's non-market valuation manual (Haab & McConnell, 2003). The use of a probit/logit approach requires that the utility model is linear. The RUM with a linear utility model where a respondent agrees to the proposal is as described in equation 4.1 and a utility model in which the respondent refuses the proposal is equation 1.2.

$$v_{1n}(y_n - c_n) = \boldsymbol{\alpha_1 x_n} + \beta_1(y_n - c_n) \tag{1.8}$$

$$v_{0n}(y_n) = \boldsymbol{\alpha_0 x_n} + \beta_0(y_n) \tag{1.9}$$

Where the familiar variables have the same values as the pervious subchapter and $\boldsymbol{\alpha_i}$ is an m-dimensional vector of parameters relating to $\boldsymbol{x_n}$. It is now possible to measure the change in utility as follows when taking into account that the marginal utility of income is the same ($\beta_0 = \beta_1$).

$$v_{in} - v_{0n} = (\boldsymbol{\alpha})\boldsymbol{x_n} - \beta_1(y_i - c_n) - \beta_0(y_i) \tag{1.10}$$

Equation 1.10 represents a barebones version of the known preferences. Note that $\boldsymbol{\alpha}$ is now used to simplify the vector expression of $\boldsymbol{\alpha_1} - \boldsymbol{\alpha_0}$. Now that these have been properly specified, the probability statement returns to as follows.

$$\Pr(YES_n) = \Pr(\boldsymbol{\alpha x_n} - \beta(c_n) + \varepsilon_n > 0) \qquad (1.11)$$

The difference between a probit and logit approach are in the distributions applied to the error term. Traditional econometric assumptions require that the error term be independent and identically distributed (IID) with a mean of 0. This suggests the normal (probit) and logistic (logit) distributions. Equation 1.11 is converted into the equivalent equation as follows, possible only by the symmetric nature of distributions.

$$\Pr(YES_n) = \Pr\big(\varepsilon_n < (\boldsymbol{\alpha})\boldsymbol{x_n} - \beta(c_n)\big) \qquad (1.12)$$

The logit method will be used in this thesis due to it having a much larger distribution tail for probabilities than the probit model. By making the assumption that ε_n is distributed logistically, it becomes normalized to have a mean of 0 and a variance of $\pi^2\sigma_L^2/3$. Using the properties of distributions, the error of the distribution can be observed as $\varepsilon_n \sim logistic\left(0, \frac{\pi^2\sigma_L^2}{3}\right)$, then rewritten as $\frac{\varepsilon_n}{\sigma_L} \sim logistic(0, \frac{\pi^2}{3})$. This is required by the fundamental principle of estimating dichotomous dependent variables. Since the dependent variable is a probability between 0 and 1, parameters are limited to their scalar multiple, which means the independent variables must be limited by an unknown variance seen in equation 1.6. In the probit model, normalization of the error term returns the following distribution of $\frac{\varepsilon_n}{\sigma} \sim Normal(0, 1)$. Therefore given the above distribution, the parameters with the logit model will be $\frac{\pi^2}{3}$ times that of the probit model, approximately 1.8 times. Thus, using the cumulative distribution function (CDF) of the standard logit, equation 1.12 is rewritten as follows.

$$\Pr(YES_n) = \left(1 + e^{\left(-\left(\frac{\alpha(x_n)}{\sigma_L} - \frac{\beta(c_n)}{\sigma_L}\right)\right)}\right)^{-1} \qquad (1.13)$$

Logit estimation for this paper uses maximum likelihood estimation routines. The log likelihood that is estimated here is as follows for a sample size of S and where $I_n = 1$ if the respondent voted for the enactment of the program.

$$\log(L(\boldsymbol{\alpha}, \beta | y_n, \boldsymbol{x_n}, c_n)) = \sum_{n=1}^{S} I_n \left[\left(1 + e^{\left(-\left(\frac{\alpha(x_n)}{\sigma_L} - \frac{\beta(c_n)}{\sigma_L} \right) \right)} \right)^{-1} \right] + (1 - I_n) \ln \left[1 - \left(1 + e^{\left(-\left(\frac{\alpha(x_n)}{\sigma_L} - \frac{\beta(c_n)}{\sigma_L} \right) \right)} \right)^{-1} \right] \quad (1.14)$$

From here, maximum log likelihood (MLL) estimations can be obtained by the β vector that maximizes $\log\big(L(\boldsymbol{\alpha}, \beta | y_n, \boldsymbol{x_n}, \boldsymbol{c_n})\big)$. These estimations are ideal in larger sample sizes but can be meaningless with smaller sample sizes. The benefit of a penalized version of this estimation is the removal of small sample bias by greatly reducing the variance in the sample. The theoretical framework of penalized maximum log likelihood (PML) is as follows. This section is largely based off of the original Firth (1993) framework as well as a application of penalization to the logit model in Rainey and McCaskey (2015). The start is to penalize the MLL by a factor equal to the square root of the determinant of the information matrix of ($|I(\boldsymbol{\alpha}, \beta)|^{.5}$) (Rainey & McCaskey, 2015). Taking the natural logarithm of this matrix and adding it to the previous equation creates the penalized version of the MLL.

$$\log(L(\boldsymbol{\alpha}, \beta | y_n, \boldsymbol{x_n}, c_n)) = \sum_{n=1}^{S} I_n \left[\left(1 + e^{\left(-\left(\frac{\alpha(x_n)}{\sigma_L} - \frac{\beta(c_n)}{\sigma_L} \right) \right)} \right)^{-1} \right] + (1 - I_n) \ln \left[1 - \left(1 + e^{\left(-\left(\frac{\alpha(x_n)}{\sigma_L} - \frac{\beta(c_n)}{\sigma_L} \right) \right)} \right)^{-1} \right] + \left(\frac{1}{2} \log |I(\boldsymbol{\alpha}, \beta)| \right) \quad (1.15)$$

Estimates are found the same way as before; finding the β matrix that maximizes $\log(L(\boldsymbol{\alpha}, \beta | y_n, \boldsymbol{x_n}, c_n))$. With these results, WTP estimations can be made.

Willingness-To-Pay Estimations

Willingness-to-pay estimations are one of the most useful approaches to communicating utility values to the public. With WTP results, one can comment on the average respondent's WTP for the program. Aggregated across the reach of a programs delivery vehicle, a total program value can be calculated as well. Given that a yes vote for the program is coded as a 1 and the no vote is coded as a 0, the linear WTP function is assumed to be:

$$\mathrm{WTP_n}(\boldsymbol{x_n}, \varepsilon_n) = \boldsymbol{x_n}\beta + \varepsilon_n \tag{1.16}$$

Where $\boldsymbol{x_n}$ is the vector of individual characteristics, β is some unknown parameter associated with the characteristics, and ε_n is the error term. A yes vote is achieved when a respondents WTP exceeds the cost presented to them (c_n). The probability of a yes vote was modeled in the previous section and is the source for $\beta = -\frac{\alpha}{\sigma}$. A level of WTP must be specified to successfully complete a vector calculation of this magnitude. For the scope of this analysis, the mean WTP will be derived.

$$\mathrm{Mean}(\mathrm{WTP}|\boldsymbol{x_n}, \beta) = \boldsymbol{\bar{x}_n}\left[-\frac{\boldsymbol{\alpha}}{\sigma}\right] \tag{1.17}$$

Where $\boldsymbol{\bar{x}_n}$ represents a vector of characteristic means and $-\frac{\alpha}{\sigma}$ represent the beta estimations produced by the Firth (1993) logit. It is with these two tools (logit estimates and the WTP calculation) that inference can be gathered from the samples perceptions and response to the Elodea infestation in the borough.

Willingness-To-Pay for Elodea Removal in the Fairbanks North Star Borough

Sampling

The survey was designed to gather a WTP estimate for the removal of Elodea from the FNSB. The population of interest was property owners in the FNSB. A random sample of 400 property owners was developed with random selection from the FNSB 2017 tax database. The final survey presented a response rate of 18.75% (75 observations). Respondents were not sent prior or follow-up postcards due to financial and time constraints.

Survey Instrument

The survey was approved by the University of Alaska Fairbanks (UAF) Institutional Review Board (IRB) (see appendix A). The paper mailing consisted of 5-page document that had a consent form, information regarding Elodea in FNSB waterways, a background section, the ballot measure, and socioeconomic questions. The paper survey can be found in appendix A. In addition to the survey materials, a prepaid business reply envelope was included in the mailing to remove any financial burden to the respondent.

The background questions of the survey asked questions regarding the respondent's thoughts an opinions on Elodea in the borough after they had read the informative section. Many of these questions were asked in the format of risk assessment scales. Respondent's perceived risks were teased out by having them respondent to questions using a scale from 1 to 5 determining the threat level Elodea presented to salmon, recreational fishing, and float planes. The next section was the ballot measure. This section included a cheap-talk script and a clear proposal of the program in referendum style.

> Thank you for your participation so far. The question below asks you how you would vote on a program to get rid of Elodea in the FNSB. This program would be paid for by applying an increase in your annual property tax bill for 4 years. After that, the increase would go away. This program would get rid of the current Elodea infestation in the FNSB. It is important you answer this question as if you were voting at a local polling

station with the assumption that if the vote passes, you will be required to pay the amount you agreed to.

If the program to get rid of Elodea in the FNSB were to happen, and it would cost you $<<AMOUNT>> per year for 4 years (total of $<<TOTAL>>), would you vote for the program? (PLEASE CIRCLE ONE)

Yes No Would Not Vote

The respondents were assigned bid levels in yearly and total cost forms (AMOUNT and TOTAL). The bids were $10 ($40), $30 ($120), $60 ($240), and $120 ($480) where their multiples of 4 were included in <<TOTAL>> (the duration of the proposed program). These bids represented surcharges that would be added to respondents' annual property tax bill. The socioeconomic section asked questions regarding the respondents age, gender, income, education, etc.

Data

These are standard questions for economics surveys and often allow us to determine how representative the sample is in comparison to census results. Table 1 includes descriptive statistics on survey questions.

Table 1 Descriptive Statistics for Survey Variables

Variable	Description	Mean	Std. Dev.
priorknow	Knowledge of Elodea prior to survey? 1=yes, 0=no	0.72	0.45
seenbefore	Seen Elodea in the borough before? 1=yes,0=no	0.49	0.50
visits	Visits to infected waterways*	2.55	1.41
fish	Times fished in infected waterways*	1.44	0.90
boat	Boat in infected waterways 1=yes,0=no	0.48	0.50
srisk	Risk of Elodea to salmon**	3.89	1.35
fprisk	Risk of Elodea to floatplanes**	3.58	1.43
rrisk	Risk of Elodea to recreational fishing**	3.89	1.42
hrisk	Respondent's concern of treatment option**	2.93	1.50
vote	Vote for program 1=yes,0=no	0.72	0.45
age	Age of respondent	55.7	13.5
income	Income of the respondent***	3.34	1.33
sex	Gender of respondent 1=male,0=female	0.46	0.50
race	Respondent's race (indicator)ł	-	-
hhsize	Size of respondent's household	1.84	2.03
depend	Number of dependents claimed by respondent	0.85	1.26
emp	Respondent's employment status (indicator)	-	-
edu	Respondent's level of education (indicator)	-	-

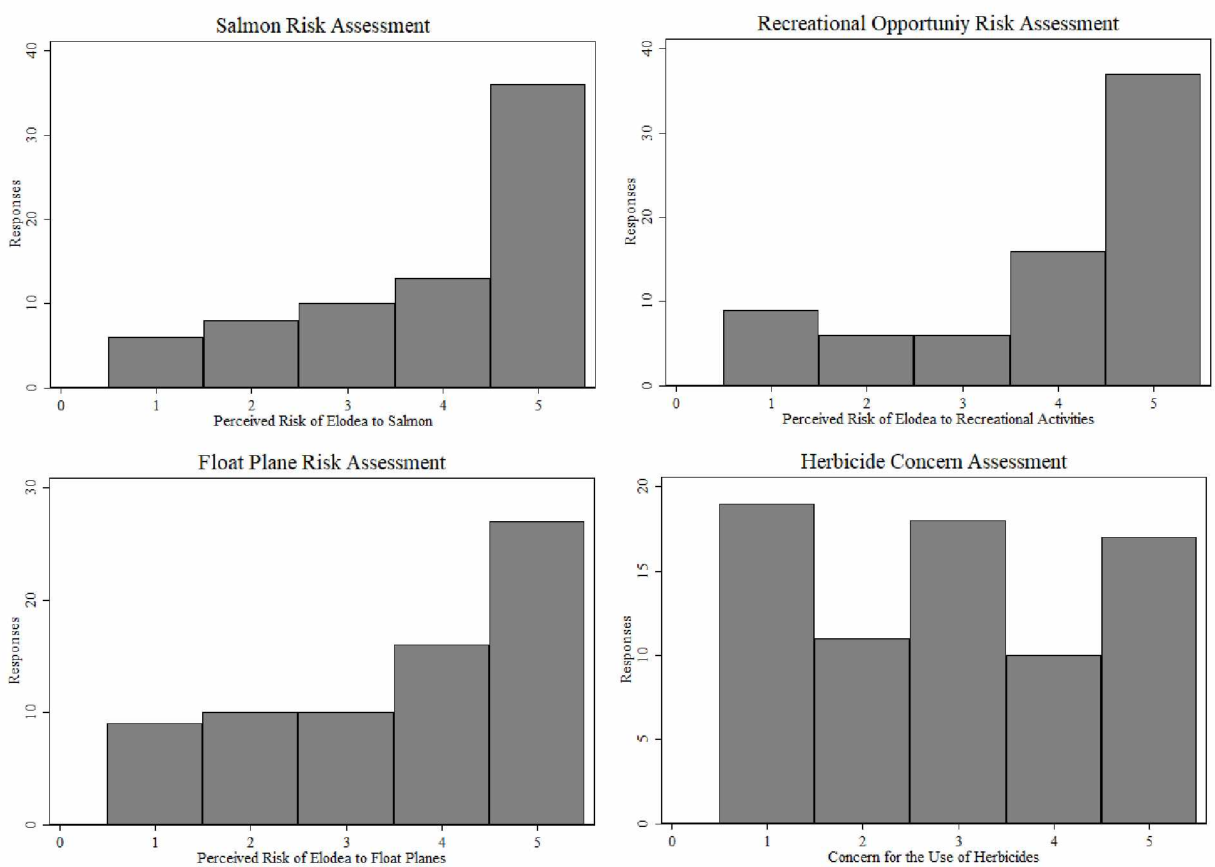
* 1=0 times, 2=1-5 times, 3=6-10 times, 4=11-20 times, 5=21-50 times, 6=51+ times
** 1=Not at all through 5 = Definitely
*** 1=0-24,999, 2=25-49,000, 3=50-74,999, 4=75-99,999, 5=100,000+
ł See Appendix A for possible values
Note: The variable descriptions are shorthand and Appendix A should be referenced for the question that was proposed to the respondent.

The survey did include a “would not vote” option to make the survey as realistic to a referendum as possible, but not a single “would not vote” response was recorded. Table 2 includes basic statistics that reflect yes and no vote statistics at each bid level to depict fairly a fairly even distribution of responses by bid level. Figure 3 represents the risk distributions by frequency or responses.

Table 2 Voting Responses by Bid Amount

Vote	Bid Amount				
	$10 ($40)	$30 ($120)	$60 ($240)	$120 ($480)	Total
Yes	15	18	13	8	54
No	2	3	8	8	21
Total	17	21	21	16	75

Figure 3 Frequency distributions of risk assessments



The salmon risk was expected to be the most skewed to the right as the survey contained accurate information on the risk that Elodea can have in salmon populations. The same assumptions apply for the risk to recreational opportunities and float planes. Though these assumptions are more relaxed as they depend on the respondent's sensitivity to that subgroup (e.g. those who do not fish or boat on the waterways may undervalue the risk as it is less important to them). As previously expected, Elodeas risk to salmon, float planes, and recreational opportunities are sharply skewed to the right indicating that most respondents felt Elodea posed a moderate to serious threat to each of the categories. The distribution obtained from how concerned respondents are with the use of herbicide in FNSB waters is more wide spread.

These risk assessment parameters are ordinally represented as 5-point scales. The scale on risk assessments were presented as a 1 representing a minimum level of perceived risk and a 5 representing a high level of perceived risk; this was true for risk assessments regarding salmon, recreation, and float planes. The herbicide concern measurement consisted of a 5-point scale in similar terms. A 1 represented a low level of concern for the use of herbicides in borough waterways and a 5 representing the opposite. The 5-point scales were reduced to binary variables with a 0 representing a 1, 2, or 3 and a 1 representing a 4 or 5. This was done to reduce the unreliability of the sample and measurement error by the respondent.

Logit estimation and mean WTP results

The general function used in the PML is as follows. This indicates that the maximum likelihood of a yes vote is dependent on the cost presented to the respondent, an appropriate measure of risk perception (in this case, this risk Elodea presents to salmon), the respondents concern for the use of herbicides in the borough, and the respondent's income.

$$vote = f(amount, risk, herbicide, income) \tag{1.18}$$

Table 3 shows the model specification that includes predictors that are statistically significant or relevant to a WTP estimation.

Table 3 PML Parameter Estimations

	Log-odds
amount	-0.0168*
	(.007)
salmon	1.9712**
	(.624)
herbicide	-1.37*
	(.612)
income	-0.1498
	(.658)
constant	1.435
	(.819)
N	75
PLL	-22.885
Wald Test	0.001***

Standard errors in parentheses. Significance indicators as follows: * $p<0.05$ ** $p<0.01$ *** $p<0.001$

This PML estimation includes the necessary components of a WTP estimation such as the bid amount and the respondent's income. This model does not include variables that were statistically irrelevant. The log-odds predictions from table 3 make up the alpha estimates needed to maximize the likelihood of a yes vote and are necessary for the WTP calculation. For inference purposes, the log-odds are raised to *e* and solved. The resulting odds-ratios are described in table 4.

Table 4 Odds Ratios

	Salmon	Herbicide
Odds Ratio	7.17	0.25

If a respondent rated their concern for the use of herbicides in the borough as high, they were ¼ times as likely to vote yes as compared to someone who reported a low-moderate concern of herbicide use. If a respondent rated the risk to salmon as high, they were 7.17 times more likely to vote yes than someone who considered the risk to salmon to be low-moderate. This gives us a measurement on what the most dramatic predictor is for the yes vote – the perceived risk towards salmon. Using the alpha coefficients from table 3, the calculation from equation 1.17 gives the mean WTP for this sample of respondents.

$$\text{Mean}(\text{WTP}|\boldsymbol{x_n},\boldsymbol{\alpha}) = \left(-\frac{1.9712(\overline{salmon}) + (-1.37)(\overline{herb})}{-0.0168}\right) \tag{1.19}$$

The mean WTP for this sample of respondents is $50.32. The constant was left out of the equation due to the mathematical nature of a constant; none of our values can take zero. From table 2, the percentage of yes votes decreases with a rising cost level. The mean WTP for this sample is within the elicited bid levels.

Discussion of Results

The original survey contained four risk measurements; salmon, recreational risk, float plane risks, and herbicide risks. It is not valid to say that recreational risks and float plane risks were insignificant in the probability of a yes vote. Apart from the herbicide risk, the first three were similar enough that large correlations existed between them causing multicollinearity in the model. The statistical power of this correlation test is low due to the small sample size.

Table 5 Correlation of Risk Assessments

	salmon	rrisk	fprisk
salmon	1.0000		
rrisk	0.7181	1.0000	
fprisk	0.6879	0.6025	1.0000

In pursuit for the model with the best fit, the following three PML estimations were run separately and their WTP values compared.

Table 6 PML Results by Risk Assessment

	Salmon Model	RecRisk Model	PlaneRisk Model
amount	-0.0168*	-0.0236**	-0.0184
risk variable	1.9712**	2.1730**	1.5366
herbicide	-1.37*	-1.0523	-1.5423*
income	-0.1498	-.2857	-0.2447
N	75	75	75
PLL	-22.885	-23.25	-24.98
Wald Test	0.001***	0.002**	0.004**
WTP	$50.32	$50.19	N/A

The recreational risk model was similar in terms of the Wald Test coefficient on model significance but removed significance of the herbicide risk parameter; which economic theory would suggest is highly relevant. The floatplane risk model removed the significance of the *amount* variable. The coefficient on *amount* is necessary in WTP calculations as it is the standard deviation in which the mean is derived from in equation 1.17. Without statistical significance, we cannot determine a significant WTP. This leaves the best model in terms of statistical significance to the salmon risk parameter that was reported in table 3.

Gathering information from table 1, the mean for fishing in the infected waterways was 1.44. The scale given in the survey instrument tells us that the respondents in this sample on average went fishing in the infected waterways between 0 and 1 times. This does not indicate the average respondent was not an avid fisherman since sport fishing opportunities are vast in the interior and throughout Alaska. The mean for boating is 0.50 which shows that about half the sample has gone boating (motor, paddle, or float craft) on either the Chena Lake, Slough, or River. Since this predictor does not collect data on the frequency, inference cannot be made from the boating parameter in respect to a level of recreational use. Most notably, a bias is present in the sample regarding an elevated level of prior knowledge of Elodea before taking the survey. Approximately 72% of respondents reported prior knowledge of Elodea. It is unlikely that the FNSB has equivalent knowledge to this sample and interpretations of this data should be made with that consideration.

The socioeconomic predictors were also not significant. Income was left out of the final WTP estimation due to statistical insignificance. The rest of the predictors (age, sex, education, employment, etc.) did not have significant impacts on the model. The mean age of the sample was approximately 56 years old. In addition, the average respondent made between $50,000 and $75,000 per year and either worked full time or was retired. A yes or no vote depends entirely on the perceived need of the program to the respondent as well as their willingness to increase their contribution to borough taxes. In this sample, respondents were highly sensitive to changes in the ecosystem revolving around the risk to salmon or the use of herbicides. It is likely that given the prior knowledge of the sample, respondents had already developed an opinion on Elodea befor taking the survey. Finally, race was highly insignificant in any specification due to 68 respondents being white and 1 respondent from each other race with no statistical difference in their survey responses.

The most significant limitation revolves around the small sample size and the bias is presents. The small sample bias is a relevant concern across all scientific disciplines engaged in data collection and analysis. Tversky and Kahneman (1971) summarized the dangers in making conclusions from models with small sample sizes. While the logistic results above may prove to be statistically significant in this sample, the ability to replicate these results without a truly representative sample is closer to 50%. Maximum log-likelihood is an excellent tool for estimating the likelihood of a yes vote give large sample sizes (a few hundred). The penalized version as described by Firth (1993) and used in this estimation greatly reduces small sample bias and variance in the estimators. Another limitation is the payment vehicle proposed in this survey. The borough does not have sales taxes making it difficult to portion out funds for invasive management. In addition, the closest to actual WTP amount is likely through the increase of fishing and boating fees by applying a surcharge. These were examined with ADFG and determined impossible. Bureaucratically, ADFG does not handle invasive species management, therefore cannot transfer fee surcharges to the Alaska Division of Agriculture. Additionally, fishing license fees increased the year before this study and there would be considerable community resistance to a ballot measure increasing fishing licenses. The financial burden fell on property tax owners due to the incentive compatibility of tax increases. Though stated WTP values may be inaccurate as a result of an increase on above average property taxes.

Conclusion

Elodea infestations have been found in 4 interior waterways. The Chena Slough, Chena River, Chena lakes, and Totchaket Slough all need treatment. While funding has been secured for this first season of treatments, sequential years of treatment remain unfunded. In February of 2018, 400 borough property owners were solicited with mail surveys. There were 75 responses. This survey was an attempt to determine the value property owners place on Elodea management. Respondents were given information on the Elodea infestation, the risks it poses, and asked questions regarding socioeconomics and risk perception. The survey included a referendum style question that asked the respondent if they would vote for a program given some randomly assigned cost level. Through a combination of yes and no votes, bid levels, and risk perceptions, the mean WTP of the survey respondent was $50.32.

Major predictors of the likelihood to vote yes are the respondent's perceived risk to salmon and concern for the use of herbicides. Respondents that assessed the risk Elodea posed to salmon to be high were 7.17 times more likely to vote yes to the referendum than those that did not. Conversely, respondents who expressed a high level of concern for the use of herbicides in borough waterways were ¼ times as likely to vote yes as a respondent who expressed low to moderate concern for the use. The sample bolstered a prior knowledge rate of 72% indicating that survey respondents had established viewpoints on Elodea prior to the survey. This unobservable characteristic introduces uncertainty in the dataset.

Appendix A

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UNIVERSITY OF ALASKA FAIRBANKS

Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

September 11, 2017

To:	Dr. Joseph Little Principal Investigator
From:	University of Alaska Fairbanks IRB
Re:	[1095997-1] Discrete Choice Elodea Management Survey

Thank you for submitting the New Project referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Discrete Choice Elodea Management Survey
Received:	September 1, 2017
Exemption Category:	*2*
Effective Date:	September 11, 2017

This action is included on the September 6, 2017 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.

Appendix B

UAF SCHOOL OF MANAGEMENT

Dear <<FIRST>>,

My name is Jesse Kaczmarski and I am conducting a study with the University of Alaska Fairbanks. An invasive aquatic weed called Elodea has started to take over recreational water ways in the Fairbanks North Star Borough (FNSB). The goal of this study is to learn about your views on a Borough program that would get rid of it. You are asked to take part in this study because you live in the Borough. Please read this form carefully. The survey should take 10 minutes to complete.

Survey Reward
Completing this survey will enter you into a drawing to win a $50 VISA gift card. We will choose the winner randomly and contact them on March 1st, 2018.

Confidentiality
- All information you provide will be confidential and anonymous.
- We will code your information with an ID number.
- We will dispose of any information that could link you to our research.

Voluntary Nature of the Study
You are free to choose whether to take part in the study. If you choose to take part in the study, you can stop at any time.

Sharing of Results
If you would like to receive the results of this survey, please write your email address on the last page of the survey. This is not required and is kept separate from your responses.

Contacts and Questions
If you have questions, feel free to contact one of the individuals listed below. If you have questions about your rights as a research participant, you can contact the UAF Office of Research Integrity at 474-7800 or uaf-irb@alaska.edu.

Jesse Kaczmarski	Joseph Little
Primary Researcher	Primary Investigator
jikaczmarski@alaska.edu	jmlittle2@alaska.edu
907-474-1809	907-474-1809

Statement of Consent
I understand the procedures described above. I agree to participate in this study. I am at least 18 years of age. By signing this document, I agree to this statement.

____

Signature of Participant
Respondent ID: <<PIN>>

Elodea Management in the Fairbanks North Star Borough
An Invasive Aquatic Plant Species Study

Survey Purpose
An invasive aquatic weed called Elodea has started to take over the Fairbanks North Star Borough (FNSB). The goal of this study is to learn about your views on a Borough program that would get rid of it.

Survey Road-map
- Information
- Respondent Background
- Ballot Measure
- Socioeconomics

Information Section
This section will give you everything you need to know about Elodea in the Borough.

Respondent Background Section
Answer some questions so we can better understand how you feel about Elodea in the Borough.

Ballot Measure
We will propose a new Borough program to fund Elodea removal. We ask you to tell us whether you would approve the measure or not.

Socioeconomic Section
This section helps us understand who is taking our survey. All responses are confidential and anonymous.

Section I - Information

Elodea takes root in lakes in rivers. The area that Elodea can cover makes it dangerous to salmon populations, boaters, and float planes.

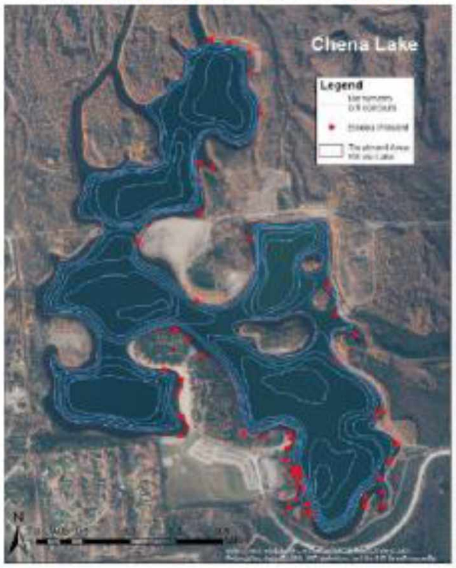
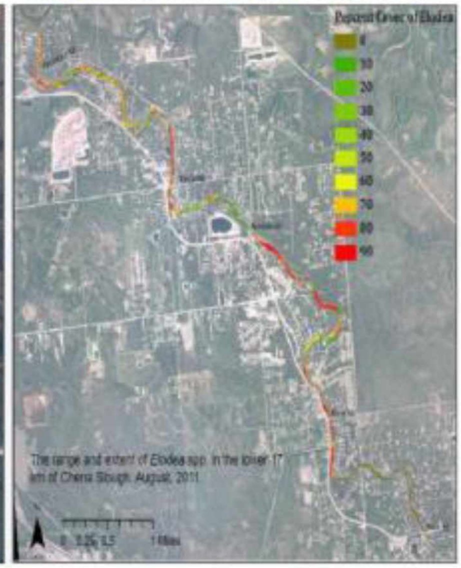
What is Elodea?
- Invasive.
- Fast growing.
- Spreads very fast.
- Not a food source for any wildlife.
- Can cover an entire body of water.
- Easily transported by humans

Why is it a concern?
- Makes it harder for salmon to spawn.
- Water moves slower, meaning there is more mud in our rivers and streams.
- Allows Northern Pike to thrive, this hurts our fishing opportunities.
- Kills native plants.
- Lowers value of lake shore properties.
- Ruins boat propellers.
- Creates danger during float plane takeoff and landing


Photographs courtesy of USFS, Kenai Watershed Forums, Wikipedia Commons, and Alaska DNR.

Where is Elodea in the Fairbanks North Star Borough?

Elodea has been found in the Chena Lake, Chena Slough, and the Chena River.

Chena Lake (50% or more is covered in Elodea)	Chena Slough (50% or more is covered in Elodea)
	

Photographs courtesy of Fairbanks Soil & Water Conservation District

So what can we do about it?

The removal project has already been approved by the State and the Federal Government. Unfortunately, this project does not have enough funding. In order to pay for this program, a small increase in property taxes for 4 years is proposed. This program will get rid of Elodea from our waters and protect against new outbreaks.

How much does it cost?

The cost of removal depends on the infected area. Current estimates are that removal will cost between $1.3 and $1.7 million for the Fairbanks North Star Borough.

How do we treat Elodea?

The State of Alaska and the Enviornmental Protection Agency (EPA) have both approved the use of Fluridone to treat Elodea in the Fairbanks North Star Borough. This an herbicide that is put in the water to kill the plant. The dead plant is then removed by hand. The use of this herbicide has had a 100% success rate on the Kenai Peninsula and other parts of Alaska. It is not considered harmful to public health or wildlife.

Section II - Background Information

Before the start of this survey, did you know anything about Elodea or that it was here in the Borough?

Yes No

Now that you know what it looks like, have you ever seen Elodea in the Borough?

Yes No

How many times have you visited the Chena Lake, Chena Slough, or Chena River in the last year? (CIRCLE ONE)

0 times | 1-5 times | 6-10 times | 11-20 times | 21-50 times | 51+ times

During the last year, how often did you go fishing in the Chena Lake, Chena Slough, or Chena River? If you do not fish, select 0. (CIRCLE ONE)

0 times | 1-5 times | 6-10 times | 11-20 times | 21-50 times | 51+ times

During the last year, have you gone boating in the Chena Lake, Chena Slough, or Chena River? (eg, canoe, motor boat, kayak, etc)?

Yes   No

Do you believe Elodea is a significant risk to salmon in the Borough?

(Not at all)				(Definitely)
1	2	3	4	5

Do you believe Elodea is a significant risk to float planes in the Borough?

(Not at all)				(Definitely)
1	2	3	4	5

Do you believe Elodea is a significant risk to fishing and boating on the Chena Slough, Chena River, and Chena Lake?

(Not at all)				(Definitely)
1	2	3	4	5

Are you concerned for the use of herbicide (fluridone) to treat Elodea in the Borough?

(Not at all)				(Definitely)
1	2	3	4	5

Section III—Ballot Measure

Thank you for your participation so far. The question below asks you how you would vote on a program to get rid of Elodea in the FNSB. This program would be paid for by applying an increase in your annual property tax bill for 4 years. After that, the increase would go away. This program would get rid of the current Elodea infestation in the FNSB. It is important you answer this question as if you were voting at a local polling station with the assumption that if the vote passes, you will be required to pay the amount you agreed to.

If the program to get rid of Elodea in the FNSB were to happen, and it would cost you $<<AMOUNT>> per year for 4 years (total of $<<TOTAL>>), would you vote for the program? (PLEASE CIRCLE ONE)

Yes   No   Would Not Vote

Section IV - Socioeconomic Questions

How old are you? ______

What is your individual income? (Choose best answer)

$0-24,999 $25,000-49,000 $50,000-74,999 $75,000-99,999 $100,000 or more

What is your gender?

Male   Female

What is your race? (Choose best fit)

Asian   Black   Latino   Native   White   Other

How many people do you live with? (Write 0 if you live alone): _____

How many dependents do you have? (Write 0 if none): _____

What is your employment status? (CIRCLE ONE)

Unemployed Part-time (20 hours or less) Full time (21 hours or more) Retired

Are you a resident of Alaska?

Yes No

What is the most education you have completed? (CIRCLE ONE)

No High School Diploma	High School Diploma	Associates	Bachelors	Masters	Professional/ Ph.D.

Thank you for your participation!

Please include all of these pages in your return mailing.

Comments or concerns can be written here. Leave your email below if you would like to receive the results of this survey.

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