11. Invasive Species Management Strategies: Adapting in the Arctic

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11.1 Introduction

Invasive species have, to date, been a relatively minor concern in the Arctic marine ecosystems because the harsh environmental conditions that stem from a combination of generally low temperatures and extreme fluctuations in seasonal light and food availability. As discussed in Gill (Chapter 1 of this volume), the rapid pace of climate change in the Arctic is bringing new urgency to concern over the introduction of non-native species and their potential threats to the marine environment and its economic productivity.

The same characteristics that have previously made the Arctic less open to the establishment and spread of invasive species are ones that make the potential problem so expansive. At stake are unique species and co-evolved systems that have taken millennia to develop. Small perturbations in the fragile Arctic ecosystems are likely to have outsized impacts both ecologically and economically. Even beyond initial polar environmental concerns, comparisons of Arctic and Antarctic systems have established that conditions in Arctic systems make it more likely that the Arctic will experience greater effects from human activity than the Antarctic due to lower alkalinity, enhanced warming, and nutrient limitations (Shadwick *et al*., 2013).

Warmer temperatures and decreases in sea-ice are bringing increased economic opportunities to the Arctic (Economist, 2012). Efforts to exploit these opportunities are increasing human presence in the Arctic and increasing both the vectors of introduction of non-native species and their intensity in terms of numbers of potential introductions, which both contribute to the ability of a new arrival to establish and evolve into an invasive species (Simberloff, 2009; Johnston *et al*., 2009).

With the changing threat in mind, this chapter focuses on the human dimensions of invasions, both from the behavioral aspects that affect them and from the policy perspective of trying to manage them. I consider that the path from a non-indigenous species to an invasive species problem in a new area such as the Arctic is a process, and that this process provides differing policy intervention opportunities that incorporate both ecological and human behavior, i.e. bio-economic modelling, in order to minimize expected damages from an invasion. When the species cross national borders, additional policy challenges arise.

Some challenges, like the Red King Crab and the Snow Crab introductions in the Barents Sea, are already attracting concern and attention in both scientific research and management efforts within and across national borders (see Sundet, Chapter 5 of this volume), but others will be more difficult to spot and manage (see Floerl, Chapter 4 of this volume) though they may have even more devastating impacts. The biology of invasions often involves lags, uncertainties, and non-linear relationships that are not easily understood. Even our ability to detect the arrival of new species and the beginnings of an invasion are functions of human behavior that should be accounted for in policy for the Arctic.

Discrepancies across species' threats are matters of both ecological uncertainty, in terms of not knowing of a threat, its presence, or the expected changes to the system it will bring, and of policy implementation. Policy implementation will necessarily vary because of the ecological uncertainty, but also can vary if stakeholders differ in the expected damages (or benefits) they will accrue from the invasion. These problems require coordinated bio-economic understanding to resolve.

11.2 A Brief Overview of Species Introductions in an Arctic Context

11.2.1 Effects of the Age of Pacific Exploration

While at first thought, remote tropical Pacific locations like the Hawaiian Islands and The Arctic Ocean and its coasts may not seem to have much in common, the cautionary lessons of the tropical Pacific with respect to invasive species are likely to be of direct use to the coming concerns in the Arctic. With some of the very same explorers – James Cook and George Vancouver, for example – advancing the paths into both locales in the late 18th Century, and direct links between locales from the whaling industry, direct parallels can be explored for insights. We can also look to other species and locations for trends that can guide improvements in invasive species management in the Arctic.

At long distances from neighboring land and/or without favorable current paths, the Pacific Ocean had formed a barrier around places like the Hawaiian and Galapagos Islands that led to the evolution of unique and fragile ecosystems which transportation advances have eroded, with the pace continuing to accelerate today with shortened sea- and air- routes.

The changes in the Pacific have been dramatic, rapid and transformative. While some of the species introductions causing the changes have been accidental, many have been intentional. For example Captain Vancouver's introduction of cattle to Hawaii, and royal tabus on these exotic and unfamiliar creatures[7] protecting them and allowing them to multiply rapidly, led to the destruction of the forests and reductions of the water supply (Kaiser, 2014). The Galapagos now have more introduced plant species than they do native species. The count for introduced plant species is over 600, meaning an average rate of introduction of 1 per year since the first western contact in 1535, compared to a natural rate of introduction estimated at 1 species every 10,000 years (Reaser *et al*, 2007).

Similarly, due to sea-ice, Arctic marine ecosystems have evolved with a level of isolation that renders them unique and fragile as well. Successful species introductions have undoubtedly been slowed more by differences in climate than differences in human behavior toward introductions of new species. For example, across all known introductions of herpetological species globally since 1850, intentionally introduced species have occurred earlier than later. (Figure 1). This should be rather unsurprising, since introductions that have net benefits to at least some stakeholders are likely to be directly undertaken by humans rather than left for more random chance opportunities for a species to hitchhike to a new environment. The Red King Crab introduction into the Barents Sea by Russia is an example of just such an intentional introduction made for market benefits (Orlov and Ivanov, 1978) (see Sundet, Chapter 5 in this volume).

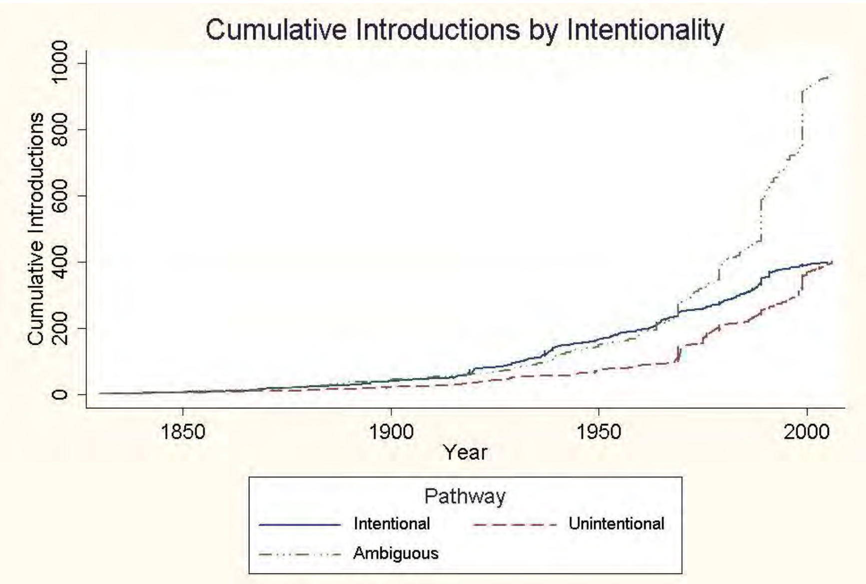
While intentional introductions are generally driven by private assessments of expected net benefits to those invested in the introduction, these may well be in conflict with social measures of net benefits. In the case of the Red King Crab, for example, not only are there ecological side effects to benthic communities that were ignored in the initial decision

[7] The only land mammal to arrive in Hawaii without human-assisted transport was a bat species. Polynesian arrivals in the 1st millennium AD brought pigs, rats, dogs, and chickens, and began the ecological changes that were intensified by western contact (Kirch, 1985).

to transplant the species but there are also potential market effects from the expansion of crab production. Alaska fishermen today complain that prices are falling due to illegal Russian catch and sales (Stewart and Tallaksen, 2013). While this is bad for Alaska fishermen, it is good for consumers of crab, and the net market impacts are not estimated here. In order to capture the full economic value a proper management system has to be in place that incorporates these conflicting incentives. With such incentive based development, the distribution of producer and consumer surplus can change over time in accord with maximum sustainable economic value.

Accidental introductions may not be aggravated by the way that the benefits of intentional ones drive a wedge amongst stakeholders trying to manage an invasion, but they still require coordinated community action at a scale relevant to the full bio-economic context, including any markets or non-market values for the threatened resources, in prevention and control. If one community, for example, finds a new species introduction becoming an invasive species problem, then neighboring communities will benefit from an early interception of the problem (See Fernandez, Chapter 10 in this volume).

Figure 1: Cumulative introductions of known herpetological species worldwide since 1830



Species data is from Kraus (2009). The timing of intentional introductions precedes that of unintentional and ambiguous cases. This is likely due to the fact that intentional introductions are likely to have expected benefits to the parties responsible for the introduction, regardless of overall expected social costs.

All actual and potentially affected parties, should, therefore, be willing to aid in the costs of such intervention, but may, for budgetary or other reasons, decline to “do their part,” exacerbating the problem for both invaded and threatened communities.

As climate evolves to be more accommodating of new species introductions (see Miller, Chapter 3 in this volume), we expect the rate of initial introductions, and their ability to take hold and transform into invasive species, to occur.

11.2.2 Anthropometric Correlates of Invasive Species Movements

The challenges of human survival in the Arctic meant that much early exploration ended disastrously, such as the Franklin Expedition of 1847. (Beattie and Geiger, 1987). These human invaders were fended off by the sea-ice. On the other hand, native communities have co-evolved with the Arctic environment over the past several millennia, with several developing subsistence economies dependent in large part on marine mammals such as seals, walrus, and whales. More successful Arctic excursions adapted to the environment. Roald Admunsen explores both the Arctic and Antarctic after learning from native Inuit how to survive and travel through arctic conditions (Katz and Kirby, 1991). Fridtjof Nansen builds a ship, the *Fram*, that he can purposefully let freeze into the Arctic ice in his attempt to reach the pole by letting the currents take him there. While he did not reach the Pole in this manner, he did survive a lengthy voyage, which was managed in great part by unexpectedly meeting up with Frederick George Jackson, after 1.5 years in the ice, on June 17, 1896 (Figure 2). In some cases, propagule pressure does not need to be very high to dramatically increase the chances of successful survival in a new environment (See Miller, Chapter 3 and Floerl, Chapter 4 in this volume).

Figure 2: F. Nansen encounters F. Jackson, June 1896. Photo from Bull (2011)

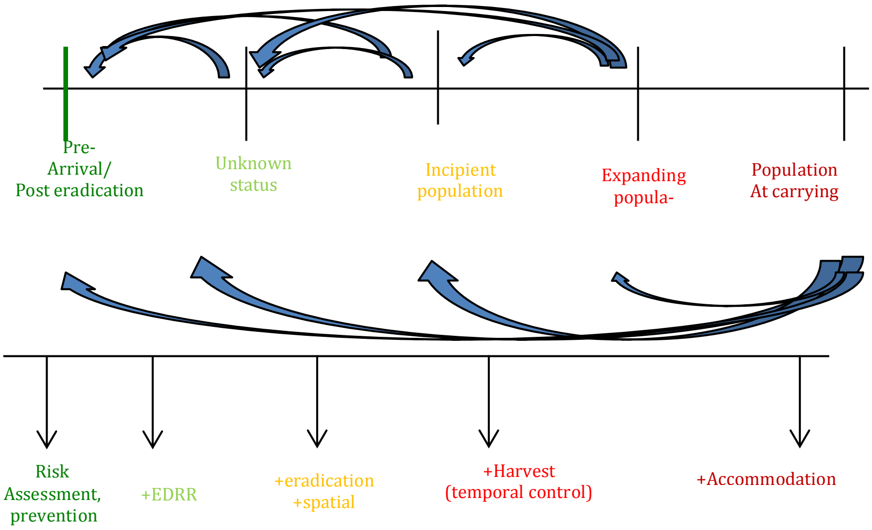
While the rate of both accidental and intentional introductions is an increasing function of trade and travel to new locations, this is not the only important factor. The movement of some species may have high external costs, while that of other species may not. One must consider the biology and the economics together to get a clear and full picture of the threat.

11.3 Management Overview of Invasive Species: Options for threatened states

11.3.1 Opportunities for Intervention

Figure 3 illustrates the interconnectedness of policy options with the biological process of invasion and time. Actions to reduce damages from invasive species may begin before the arrival of any new species to an area and continue through the spread of a new species to its biological carrying capacity. In the case of marine invasive species, limited management interventions may be possible after the arrival of a species because the environment is often more difficult to manage than for terrestrial systems. These limitations make it perhaps more necessary to consider the full spectrum of policy options when making decisions about prevention because the costs of control may be so prohibitively high. See, for example Niemi *et al*, Chapter 7 of this volume; Floerl, Chapter 4 of this volume; Bax *et al*, 2001; Ruiz and Carlton, 2003.

Figure 3: Integrated management of Biological Invasions



11.4 Prevention and Early Detection (ED) and Rapid Response (RR) Strategies

At low potential population levels, when a potential invader has not yet become a problem, the management options should focus not only on prevention of arrivals at obvious points of entry (e.g. ports, ship hulls) but also on a process of early detection (ED) and rapid response (RR) that also includes expected damages and costs of investigating the invasion in the decision-making (Kaiser and Burnett, 2010).

Preventative measures are imperfect, probabilistic, and will fail. Prevention can only be expected to buy time, rather than provide an impenetrable shield around an ecosystem. Early detection systems are monitoring systems that increase the likelihood of identifying the arrival or incipient population of a potential invader. Rapid Response systems provide actionable responses to eliminate or spatially contain the new invasion. Together EDRR can function to protect ecological and economic assets at risk in relatively low cost ways. For example, preventative efforts to keep the Brown Tree Snake arriving in Hawaii from Guam have knowingly failed several times, and may have unknowingly failed others.

EDRR targets these unknown cases by enlisting the public's help through awareness and a hotline for reporting snake sightings and then deploying a team of trained snake spotters for several weeks' worth of night searches in the region of the sighting. In this case, as sightings occur in places that humans use, they are more likely to accrue damages to humans from bites and other interactions than snakes in other areas, so the damage minimization process is built in (Kaiser and Burnett, 2010). There are, of course, other potential ecological damages that are separate from human interactions which this sort of EDRR will systematically miss. Awareness of such concerns is important to policy efficiency and will be particularly important in the Arctic where direct human-species interactions are not likely the primary source of damages from invaders (see valuation discussion below).

Policy Options for prevention can be categorized as either incentive based or command-and-control. Command and control options are regulation via "green/white" lists that include all species that may be introduced to an area (knowingly) or "red/black" lists that include all species that must be kept out of an area (knowingly). Note that these policies only target intentional introductions. Green lists are less permissive than red lists in that they ban the introductions of species about which little or nothing is known. These species may have net benefits from introduction (e.g. many agricultural products have been introduced around the globe with positive net gain) but cannot occur under the policy regime of a green list, potentially stifling growth and economic prosperity. On the other hand, the green list system is better at protecting the status quo against unexpected consequences. Green lists, being less permissive, may be more difficult to negotiate across borders and may lead to increases in smuggling, which makes prevention more costly (Burgiel *et al*, 2006; Wittenberg and Cock, 2001).

Incentive based regulations, e.g. those targeting economic behavior such as taxes or subsidies, focus on aligning the interests of those who are causing the introduction with the overall expected social damages. As such, they are more targeted policy than the command and control options, such as prohibitions, technology mandates and quotas, and can therefore in theory operate at lower costs to society by avoiding costs from e.g. hierarchical management and control, information gathering, and monitoring and enforcement. Such incentive based systems include certification systems, under which any new introductions must be researched and shown to lead to acceptable expected costs before the introduction can be made, and liability or insurance systems, where the expected costs are borne by the introducers. Again, these regulations focus mainly on intentional introductions (Inglis *et al*, 2012).

In the Arctic, intentional introductions may not seem like the primary pathway for new invasions. However, with approximately four million people inhabiting the Arctic (ACIA, 2004), the case of the Red King Crab suggests that there are likely gains to be had from introducing new marine species. As the climate changes, some species that already spend some portion of the year in the Arctic may expand both their spatial and temporal ranges at the expense of existing endemic ice-obligate and ice-associated species (Moore and Huntington, 2008). Some of these endemic species are hunted for subsistence, and communities might look to ways to enhance marine productivity. Or, as with the Red King Crab case, individuals or nations may find the climate changes in the Arctic conducive to the introduction of other marine resources. Thus some consideration to policy should be given to limiting intentional introductions.

While the above discussion focuses on reducing impacts from intentional introductions, policy options aimed at accidental introductions such as would occur through ballast water exchange or hull fouling are clearly important policy tools needed in the Arctic. These are discussed at greater length in Section 2 (Miller, Floerl) and Chapter 10 (Fernandez) of this volume. In short, these policies need to focus on regulating the bio-economic conditions rather than just the economic or ecological ones independently. For example, ships that are only in transit through the Northern Sea Route (or Northwest Passage, eventually) may not need as stringent controls as those that are stopping at ports along the way. Additionally, slow moving or stationary equipment, like the recreational boats that might eventually dot Arctic waters for tourism and leisure, or oil rigs set to the ocean floor, are likely to need more attention than faster ships that are used for trade who will spend time neither accumulating nor discharging many species in similar waterways.

11.5 Control (Spatial Containment and/or Population Reduction)

If prevention and EDRR fail, so that an incipient, self-sustaining population exists in the new location, the option of limiting intervention to controlling either the spatial extent of the invasion or the biomass levels associated with the invasion become other possible intervention policy options. This is the stage of intervention we are now at with the Red King Crab. While efficient policy that minimizes expected net damages would consider the costs and benefits of the Crab across time in terms of its likely movements into new areas, markets for crab over time, and ecological and/or economic damages from the crab to other species and the whole benthic ecosystem, existing policy has not been so thorough. The result is that the crab continues to spread eastward and has become a market good upon which livelihoods are beginning to depend in Norway and Russia (Jørgensen and Nilssen, 2011). This makes future management decisions even more complicated as one weighs more easily measurable gains from the crab against difficult valuations in changes to the ecosystem and its productivity. The 2007 management decision to have an open access fishery for crab west of 26°E in an attempt to stem the invasion does not appear to be successful (Falk-Petersen *et al*, 2011).

11.5.1 Adaptation

As there are significant economic benefits to the harvest of the crab, and the crab is already being managed in both its native range (Alaskan waters) and its expanded Russian and Norwegian range with quota systems that work to limit harvests so that the fishery is sustainable over a long time horizon, the long term control strategy will likely be one of fisheries management for stable economic outcomes focusing on producer and consumer surplus from market transactions rather than for full ecological considerations that might include protecting biodiversity values or ecosystem services with direct or indirect values to society. In adaptation to the new conditions, the one-time chance to preserve the benthic ecosystem associated with the newly invaded habitat will be lost, at potentially tremendous cost.

This describes one of the biggest concerns of invasive marine species in the Arctic: that we will lose the stock of nature built up over millennia and replace it with a less diverse, less resilient system. The costs to society might be high and yet difficult to measure. We turn now to discussions of valuation and the role of valuation in policy making for invasive species.

11.6 Valuation of what is “at stake”

It is important to realize that just as the ecological consequences vary with the level of invasion, the expected costs and benefits of interventions are also dynamic. Any calculations of policy costs must be contingent on the stage of invasion and level of prevention and/or control desired over the long run.

Failure to make policy decisions regarding invasive species over the long run can be extremely costly to anyone who garners any sorts of value from the threatened ecosystems – privately or socially. Decision-making may be through private cooperation or public management, and may be local, national, regional, or global, depending on the bio-economic conditions of the threat. In the worst case scenarios, any money or effort spent on prevention or control is swamped by the ecological changes and the end tally for the damages is higher than if no intervention were attempted at all (Kaiser, 2006). Unfortunately the piecemeal funding opportunities for invasive species management often make this all too real of a problem (Kaiser and Burnett, 2010). One way in which to avoid this problem is, like Nansen, to work with nature and the sea-ice and ecology rather than against it. A dollar spent on spatial containment of a new invader, keeping it, for example, east of a certain longitude, such as Norway seeks to do with the Red King Crab (Sundet, Chapter 5 of this volume), may bring much more success than reduction in biomass across the entire range, for example, if there are spatially differentiated costs or benefits from protecting the existing ecosystems. On the other hand, if the ecosystem is widely similar, it may be more efficient to simply target biomass reduction at any location than to worry about spatially controlling the spread (Frid *et al*, 2013). In any case, one must determine the values of the assets one wishes to protect through the invasive species management policy as well as the costs of the intervention as functions of the invasion level. It is generally far cheaper, for example, to remove invasives from a large concentrated population than it is to hunt down the last specimen of an invader across a wide range.

These considerations lead to a balancing act between present and future actions and their consequences. Optimal policy would provide intervention activities today (prevention, EDRR, and/or control) until the last dollar spent on the intervention, was just equal to the marginal benefit of that dollar spent, not only in the current consequences but also in the future expected costs. These future expected costs are based on the population that is left remaining after current intervention activities are undertaken and its ability to reproduce and spread, and the damages from those future ecological changes, and the future costs of intervening to manage them. (See, for example, Burnett *et al*., 2007). In addition, policy expenditures *across intervention options* should also equate marginal benefits and costs. In other words, the last dollar spent on prevention activities should bring the same expected return as the last dollar spent on control/containment policies for a species, or one could improve outcomes by moving resources from the lesser productive policy to the more productive one. (Burnett *et al*., 2008).

11.7 Valuation techniques for Non-Market Resources Damaged by Invasive Species

There are two types of valuation techniques that economists have developed (and continue to develop) to address valuation of non-market amenities such as most of the ones generated by marine resources and ecosystems in the Arctic (see, e.g. Garrod and Willis, 1999; De Groot *et al*, 2002; Freeman, 2003; Atkinson *et al*, 2006; Bennett, 2011; Barde and Pearce, 2013 for overviews and cases of environmental valuation). The first are revealed preference techniques, where economists try to parse the portions of real market interactions such as tourism dollars spent or trips to see polar bears at zoos that are reliant on the ecosystem conditions under threat. These are also known as hedonic methods. The alternatives are stated preference techniques, or direct survey methods.

We discuss these with the example of the polar bear, for which a preliminary study using a variety of (imperfect) methods exists, resulting in a very rough average estimate of a willingness to pay by Canadians for polar bear preservation equivalent to 1% of Canadian household income per year (Ecoresources Consultants, 2011).

11.7.1 Revealed Preference methods

As mentioned, revealed preference methods tie market activities to aspects of ecosystems and non-market amenities (see, e.g. Bateman 1993; Bennett, 2011; Hanley *et al*, 2013). Subsistence hunting, sport hunting, and polar bear viewing in their natural habitat are all activities that can be related to market expenditures.

Polar bear viewing and sport hunting both require direct investments that are made due to the existence of the polar bear. Of course, not all expenditures can be entirely attributed to the bear. For example, if warm winter clothing is purchased for the trip, the portion of the value of the clothing that should be assigned to polar bears is probably not the entire value of the wardrobe, since it can be used for many other cold-weather outings for years. Or consider that you wanted to see polar bears in their native habitat, and that you have a college friend who lives in Churchill, Canada. You plan to visit your friend for a week and spend one day devoted explicitly to finding polar bear viewing. Only 1/7 of your expenses should probably be attributed to bear viewing. It is helpful, then, to have a sample of expenditures across activities to try to parse out what is, on average, attributable to the bear and what expenditures might have been due to other reasons. A particular type of revealed preference method, the travel cost method, is most applicable for such cases (see e.g. Barde and Pearce, 2013; Hanley *et al*, 2013).

Expenditures on hunting licenses are another market item tied to the polar bears' continued existence. One might be tempted to assume that the value of the licenses sold is a good estimate for the hunting value of the bear. While it may be the best proxy available, it is probably not a great estimate however, unless there is price variation in the permits so that a demand curve can be developed (Bennear *et al*, 2005). This is because such licenses are rarely distributed in an open market system. It may capture the lowest value of the bear to hunters, since the hunt cannot happen without it and hunters who value the hunt less than the license cost will not partake. But it is not likely to capture the upper end, nor is it easily parsed of any other related activities, such as the camaraderie of the hunt or the scenic beauty encountered. Similarly, subsistence hunting values are in one sense measurable by the food expenditures that would have to be made if the hunt were not available. This expenditure might miss many other associated benefits, however, including cultural heritage values and lifestyle satisfaction. One must be careful in applying these valuation methods to truly capture the asset under threat (De Groot *et al*, 2002). However the biggest disadvantage of revealed preference techniques is that they cannot be used to measure non-use values, or the values to individuals who make no expenditures directly related to the existence of the polar bears. For this, we must turn to survey methods.

11.7.2 Direct (Survey) Valuation Techniques

Survey valuation techniques are also known as contingent valuation methods or survey methods (Hanley *et al*, 2013; Carson, 2012a). As practiced by economists today, they tend to be framed as something called conjoint analysis, in which individuals are asked, in surveys, to choose between scenarios that trade off some financial cost against some non-market amenity. For example, if we wanted to estimate how much polar bears were worth to the average American, who is unlikely ever to travel to see one but might get a "warm glow" from their continued existence nonetheless, or hope to preserve them for their children and future generations, for example, we would survey a sample of the population and ask them questions like the following:

Would you choose:

A. A tax of USD 5/year that increased the probability of the continued existence of polar bears for at least 1,000 years from 45 to 55%, or

B. No taxes for polar bear preservation and a continuing probability of 45% that the bears will survive for the next 1,000 years?

As one surveys different individuals, the cost and the change in probability are varied so that statistical analysis can determine the expected willingness to pay for increases in the probability of survival as a function of the existing probability.

Such methods are valuable because they are the only tools we have to address non-market values. They come under fire, however, for potential biases that are mainly based in concerns that the questions are hypothetical and do not commit the surveyed individuals to make the expenditures in question. For more on this debate, see JEP 2012 symposium (Kling *et al*, 2012; Carson, 2012b; Hausman, 2012).

11.8 Using valuations in invasive species management

For monetary values to affected parties to be most useful to the discussion of invasive species management, the expected changes in the environment that will change the values must be measured at the same scale as the potential intervention. That is, if an invading species threatens the polar bear by reducing the availability of its prey, for example, then the connection must be made between preventing or removing either a biomass measure or a spatial area of an invasive species that is directly translatable to the survivability of the polar bear and its values to society, which may include direct, indirect, and non-use values across a range of interested parties. Again, we see that the economics and the ecology must be tightly interconnected in order to develop the best policies.

In the absence of such knowledge, the Arctic may be one of the cases where erring on the side of precaution outweighs economic considerations. The slow ecological growth conditions and the fragile, unique habitat make it more likely that small perturbations in the system will have large and potentially unanticipated outcomes (Shadwick *et al*., 2013).

11.9 Conclusions

This chapter seeks to provide an overview of the management of potential invasive species in the Arctic from a bio-economic perspective. To most effectively address the threat of invasive species, the whole series of events from pre-introduction through establishment, spread, and eventual saturation of viable habitat must be considered in a simultaneous integration of human and ecological behaviors. Non-market valuation is an important part of this integration. Appropriate valuation reflecting marginal damages from invasive species not only allows decision-makers at all levels to assess the tradeoffs inherent in the costs and benefits of an invasive species policy option, as well as the costs of failing to act against invasions, but also helps to address questions of why, where and how invasive species should be combatted by allowing comparisons in outcomes across policy options.

Even with the natural barriers that the Arctic climate has historically provided against invasions, marine invasive species in the Arctic have already been both intentionally (e.g. Red King Crab in Russia) and unintentionally (e.g. Snow Crab in Norway) established and identified. Countless others may already be underway, and certainly the increased human use of Arctic waters will increase the probability of new invasions. Policy options are the most flexible before invasion; the potential to minimize damages from invasions only shrinks as time passes. Thus the faster good preventative policy and early detection monitoring programs can be agreed upon and established amongst various Arctic states, the higher the expected net gain to all parties.

11.10 Works Cited

ACIA (2004). *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*. ACIA Overview report. Cambridge University Press. pp. 140.

Atkinson, S. M., Mourato, S., & Pearce, D. (2006). *Cost-Benefit Analysis and the Environment*.

Barde, J. P., & Pearce, D. W. (Eds.). (2013). *Valuing the environment: six case studies*. Routledge.

Bateman, I. J. (1993). Valuation of the environment, methods and techniques: revealed preference methods. *Sustainable Environmental Economics and Management: Principles and Practice.* Belhaven: London.

Bax, N.; Carlton, J. T.; Mathews-Amos, A.; Haedrich, R. L.; Howarth, F. G.; Purcell, J. E.; Rieser, A.; Gray, A. (2001). The Control of Biological Invasions in the World's Oceans. *Conservation Biology 15*(5):1234-1246. DOI: 10.1046/j.1523-1739.2001.99487.x.

Beattie, O. and J. Geiger (1987). *Frozen in Time: The Fate of the Franklin Expedition*. London: Bloomsbury.

Bennear, L. S., Stavins, R. N., & Wagner, A. F. (2005). Using revealed preferences to infer environmental benefits: Evidence from recreational fishing licenses. *Journal of Regulatory Economics 28*(2), 157–179.

Bennett, J. (Ed.). (2011).*The International Handbook on Non-Market Environmental Valuation*. Edward Elgar Publishing.

Bull, J.B. (2011). *Fridtjof Nansen: A Book for the Young*. Trans. M.R. Barnard. Project Gutenberg ebook.

Burgiel, S., Foote, G., Orellana, M., & Perrault, A. (2006). Invasive alien species and trade: integrating prevention measures and international trade rules. *The Center for International Environmental Law and Defenders of Wildlife, Washington, DC*.Burnett, K.; D'Evelyn, S.; Kaiser, B.; Nantamanasikam, P., and J. Roumasset. Beyond the Lamppost: Optimal Prevention and Control of the Brown Treesnake in Hawaii (2008), *Ecological Economics*, 67, pp. 66–74.

Burnett, K.; Kaiser, B.; and J. Roumasset (2007). Economic Lessons from Control Efforts for an Invasive Species: *Miconia calvescens* in Hawaii *Journal of Forest Economics 13(2–3):151–167*

Burnett, K., Pongkijvorasin, S., and J. Roumasset (2012). Species Invasion as Catastrophe: The Case of the Brown Tree Snake. *Environmental and Resource Economics* 51(2): 241–254.

Carson, R. (2012a). *Contingent valuation: a comprehensive bibliography and history*. Edward Elgar Publishing.

Carson, R. T. (2012b). Contingent valuation: a practical alternative when prices aren't available. *The Journal of Economic Perspectives*, 27–42.

De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological economics 41*(3), 393–408.

Ecoressources Consultants (2011). *Evidence of the Socio-Economic Importance of Polar Bears for Canada*. Report prepared for Environment Canada.

Economist, The, (2012). *The Vanishing North*, Jun 16th 2012. Available online at http://www.economist.com/node/21556921

Falk-Petersen, J.; Renaud, P.; and Anisimova, N. (2011). Establishment and ecosystem effects of the alien invasive red king crab (*Paralithodes kamtschaticus*) in the Barents sea – a review. *ICES Journal of Marine Science 68*(3):479–488.

Freeman, A. M. (2003). *The measurement of environmental and resource values: theory and methods*. Resources for the Future.

Frid, L; Knowler, D.; Myers, J.H.; Scott, L.; Murray, C. 2013. A multi-scale framework for evaluating the benefits and costs of alternative management strategies against invasive plants. *Journal of Environmental Planning and Management 56*(3): 412–434.

Garrod, G., & Willis, K. G. (1999). *Economic valuation of the environment: methods and case studies* (pp. 132–133). Cheltenham: Edward Elgar.

Hanley, N., Shogren, J., & White, B. (2013). *Introduction to environmental economics*. Oxford University Press.

Hausman, J. (2012). Contingent valuation: from dubious to hopeless. *The Journal of Economic Perspectives 26*(4), 43–56.

Inglis, G., Floerl, O., & Woods, C. (2012). *Scenarios of Vessel Biofouling Risk and their Management.MAF Research Project RFP11832.* Ministry of Agriculture and Forestry, Wellington, 41–93.

Johnston, E.L.; Piola, R.F.; and G.F. Clark. (2009). The Role of Propagule Pressure in Invasion Success. *Biological Invasions in Marine Ecosystems*: 133–151.

Jørgensen, L.L. and E.M. Nilssen (2011). The Invasive History, Impact, and Management of the Red King Crab *Paralithodes kamtcshaticus* off the coast of Norway. *In the Wrong Place – Alien Marine Crustaceans: Distribution, Biology and Impacts*. Eds. Galil, B.S.; Clark, P.F. and J.T. Carlton. P. 511–526

Kaiser, B. (2006). Economic Impacts of Non-indigenous Species: Miconia and the Hawaiian Economy, *Euphytica 148*(1–2): 135–150.

Kaiser, B. and K. Burnett (2010). Spatial economic analysis of early detection and rapid response strategies for an invasive species. *Resource Energy Econ*. doi: 10.1016/j.reseneeco.2010.04.007

Katz, C. and A. Kirby (1991). In the nature of things: the environment and everyday life, *Transactions of the Institute of British Geographers* 15(3): 259–271.

Kirch, P.V. (1985). *Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory*. Honolulu: University of Hawaii Press.

Kling, C. L., Phaneuf, D. J., & Zhao, J. (2012). From Exxon to BP: Has some number become better than no number? *The Journal of Economic Perspectives*, 3–26.

Kraus, F. (2009). *Alien Reptiles and Amphibians: A Scientific Compendium and Analysis*. Springer-Verlag.

Orlov, Y.I. and Ivanov, B.G. (1978). On the Introduction of the Kamchatka King Crab Paralithodes camtschatica (Decapoda: Anomura: Lithodidae) into the Barents Sea. *Marine Biology 48*(4): 373–375.

Reaser, J.K; Meyerson, L.A.; Cronk, Q.; De Poorter, M.; Eldrege, L.G.; Green, E.; Kairo, M.; Latasi, P.; Mack, R.N.; Mauremootoo, J.; O'Dowd, D.; Orapa, W.; Sastroutomo, S.; Saunders, A.; Shine, C.; Thrainsson, S. and L. Vaiutu (2007). Ecological and socioeconomic impacts of invasive alien species in island ecosystems. *Environmental Conservation 34*, pp 98–111. doi:10.1017/S0376892907003815.

Ruiz, G. M.; Carlton, J.T., eds. 2003. *Invasive Species: Vectors and Management Strategies*. Washington, DC: Island Press.

Shadwick, E. H.; Trull, T. W.; Thomas, H.; Gibson, J. A. E. (2013. Vulnerability of Polar Oceans to Anthropogenic Acidification: Comparison of Arctic and Antarctic Seasonal Cycles. *Scientific Reports* 3 (Article #2339) http://dx.doi.org/10.1038/srep02339

Simberloff, D. (2009). The Role of Propagule Pressure in Biological Invasions. *Annual Review of Ecology, Evolution, and Systematics 40*:81–101.

Strayer, D. (2009). Twenty years of zebra mussels: lessons from the mollusk that made headlines, *Frontiers in Ecology and the Environment 7*(3).

Stewart, J. and E. Tallaksen (2013). King crab prices keep dropping on suspected IUU fishing. *Undercurrent News*, May 17, 2013. URL: http://www.undercurrentnews.com/2013/05/17/king-crab-prices-keep-dropping-on-suspected-iuu-fishing/

Wittenberg, R., & Cock, M. J. (Eds.). (2001).*Invasive alien species: a toolkit of best prevention and management practices*. CABI.