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The Issue and Impact on Economy of Aquatic Invasive Species in the USA.

Abstract

Invasive species are a growing threat in the United States, causing losses in biodiversity, changes in ecosystems, and impacts to economic enterprises such as agriculture, forestry, fisheries, power production, and international trade. The costs of preventing and controlling invasive species are not well understood or documented, but estimates indicate that the costs are quite high, in the range of millions to billions of dollars per year. EPA's Office of Water needs to develop a national estimate of the costs of aquatic invasive species and the benefits of control. The review includes studies on fish, mollusks, crustaceans, invertebrates, and plants. There are few theoretical and even fewer empirical, studies dealing with the economic costs of aquatic invasive species. Due to the high level of invasions in the Great Lakes, a number of studies focus on species found there and on Zebra Mussels in particular. The aquatic studies reviewed show values ranging from several hundreds of thousands of dollars a year to tens of millions of dollars a year. It seems apparent that a systematic approach is needed to develop a consistent method to estimate such costs. As the literature points out, invasive species and their control have definite public good aspects and thus call for some level of government intervention. However, to what extent and what form that intervention takes place depends on numerous of issues associated with both the region and the species involved. Optimal policy appears to be as unique as the individual species or ecosystem it is attempting to control and protect.

Introduction

Invasive species are a growing problem and threat in the United States, causing losses in biodiversity, changes in ecosystem, and affects mostly the economic enterprise such as forestry, fishery, agriculture, power production and the international trade. An "invasive species by definition is non-native to the ecosystem or is likely to cause an environmental harm or harm to human health" according to the (Executive Order 1999). Not all non- native or non-indigenous species become invasive. Some fail to thrive in their new environment and die off naturally, however other survives. Those species that do meet the definition have the ability to cause great harm on the ecosystem. About 400 of the 958 species listed as threatened or endangered under the Endangered Species Act are consider being at risk simply because of competition wit, and predation by, invasive species (Wilcove et al.1998). The routs by which species are introduced into new environment are called pathways. Some species that become invasive are imported internationally, and escape from captivity or are often carelessly released into the environment. Other invasives are unintentionally imported, arriving through livestock, produce, or by transport such as packing materials or ship's. Fish, shellfish, and parasites have been introduced unintentionally into the U.S. in infected stock intended for aquaculture. Crates and containers can harbor snails, slugs, beetles and other organisms. Military cargo transport may also harbor unintended species. Stimulated by the expansion of the global transport of goods and people, the numbers and costs of invasive species are rising at an alarming rate (NISC 2001). The cost to preventing and controlling invasive species is not well understood or documented, but estimates indicate that the costs are quite high, in the range of millions to billions of dollars per year (OTA 1993, Pimental et al. 2000). EPA's Office of Water is interested in developing a national estimate of the costs of aquatic invasive species and the benefits of control. In general, this review is limited to studies dealing with aquatic or aquatic related species and does not include estimates of the costs of invasive agricultural weeds and other purely terrestrial species. This study is dealing with the general economic aspect of the problem. Many of the studies focus on aquatic invasive species in the Great Lakes, due to the large amount of ship traffic and corresponding potential for invasion from ballast water. Since the 1800's, over 145 nonindigenous aquatic species have become established there, including 24 species of fish, 9 mollusks, and 61 species of plants (Dohnahue, 1999; Horan and Lupi 2004).

General Cost Studies

There are two studies, which tried to estimate the total cost of invasive species in the United States. The first is "Harmful Non-Indigenous Species in the United States" by the Office of Technology Assessment (OTA) of the U.S. Congress (1993). In details, both ecological and economical estimated impacts of those invasive species considered harmful rather than all invasive species inhabiting the nation. Moreover, it considers native U.S. species outside of their natural range as invasive. Over the period from which the data was available from 1906-1991, 59% of introduced species to the U.S. have caused economic or ecological harm. This report estimated the total coast of damages related to 79 harmful species to be between $97- 137 billion. This estimate is only based on the cumulative coast of invasive species to fishery, forestry, agriculture and other water uses, buildings and natural areas. When comes to the aquatic invasive species OTA took under consideration 111 species of fish, which only 88% of total known as invasive .

Furthermore, 76 of the fish species was intentionally introduced, 35 of them have caused harm and 26 of them were introduced unintentionally introduced in the U.S. The list of high impact aquatic species includes the Sea lamprey, Zebra Mussel, and Asian clam. OTA estimated that the cumulative loss to the U.S. for the period 1906-1991 for 3 harmful fish species was $467 million (1991 dollars) and $1,207 million for 3 aquatic invertebrates. In terms of aquatic or riparian plants, high impact species include the Salt Cedar, Purple Loosestrife, Melaluca, and Hydrilla. OTA reports that spending on control of aquatic plants in the U.S. is $100 million per year. Pimentel et al. (2000) produced a more recent study, attempting to update and expand these costs estimates. At the time of the OTA study, they estimated the total number of harmful species in the U.S. to be 4,500. Pimentel et al. (2000) estimated 5,000and by 2004 that estimate had increased to over 6,000 (Burnham 2004). Invasive weeds are spreading and invading approximately 700,000 ha/year of U.S. wildlife habitat (Pimentel et al. 2000). Examining a series of case studies, the Pimentel study estimates the total economic damages and associated control costs for the U.S. due to "harmful non- indigenous species" is $138 billion annually. They attribute their higher estimate to the broader base at which they look and the increase in the economic cost estimates available for many invasive species. However, they also characterize their cost estimates as low because the study does not take into account the extensive ecosystem damage caused by these species. The Pimentel study has a number of flaws. First, the methods applied to estimating costs are anecdotal in nature. No systematic empirical methods of estimating costs, which would have provided a statistical basis to judge the validity of the estimates, were applied. There was also no attempt to incorporate ecosystems services. Finally, there was no explicit consideration of the potential benefits provided by some of these invasive species (such as the recreational benefits from introduced game fish). While the effects arrived at by Pimentel are widely cited, these flaws tend to undermine the credibility of the numbers. Both the OTA (1993) and the Pimentel et al. (2000) studies illustrate the difficulty in quantifying the harm done to both the economy and the ecosystem by invasive species. Both studies point to the lack of data available to adequately estimate the costs that would help put the problem in some perspective. In further study, Pimentel et al. (2001) look at the impact of invasive species on 6 countries, including the United States, stating that over 120,000 invasive species have invaded these regions at estimated costs of over US$314 billion per year in damages. For the U.S., they report estimated US $ 1 billion a year in environmental losses from fish alone. Government spending on invasives may be a furthe r guide in estimating costs. In 1999/2000, the federal government spent $459 million and $556 million respectively for invasive species activities. For fish and aquatic invertebrates, $20.4 million in federal funding was given out in 1999 (GAO, 2000). The U.S. Geological Service Aquatic Nuisance Species Program had a $5.5 million budget for the National Biological Research Division's Invasive Species Program. The U.S. Coast Guard has a total of $4.5 million annually for invasive related activities, mostly focused on ballast water programs and surveys (Sturtevant and Cangelosi, 2000).

The Theory on Economic Models and

Research

Very few studies dealing with invasive species exist in the formal economics literature. Of those that are available, they primarily concentrate on theoretical considerations with relatively little empirical analysis. A number of papers concentrate on issues related to trade. Others develop models of the risk of invasive species or incorporate both ecological and economic models.

Evans (2003) lays out the economic dimensions of invasive species and why economics is increasingly called upon to understand the issues. The causes of biological invasions are often related to economic activities and furthermore, the economic consequences of invasives are broader than just direct control costs and damages. The economic impacts of trade barriers that attempt to prevent an invasive species from entering the U.S. are becoming more complicated. Economic modeling expertise is important for understanding the issues involved. Economic models of the value of no marketed environmental and health effects can be called upon to understand many of the impacts of invasives, beyond control costs. Evans notes that the impacts of invasives can be classified into 6 types: production, price and market effects, trade, food security and nutrition, and financial costs.

Perrings et al. (2002) frame the issue of control of invasive species as a public good and discuss why both the causes of invasive species and the solutions are primarily economic in nature. They point out that the full economic costs of invasive species include the effects on native ecosystems and the human populations that depend on such ecosystems, and are not limited to just the damage or control costs. The authors point out that little investigation has been done into the economic and social causes of biological invasions, which are often the result of decisions related to , land use and conversion of habitat , the use of certain species in production or consumption, and global movement of people and products. Economic drivers such as property rights, trade rules, and prices often influence these decisions. Human behavior influences the probability of invasives becoming established as well as their spread, specifically how people respond to the threat of invasives by either mitigation or adaptation. The control of the risk of invasives has a public good element, in the sense that the benefits of control are neither rival nor exclusive.

In other words, control can protect one person or group without excluding those benefits on another or reducing the benefit implying the need for government involvement. Further, effective control of invasives is only as good as the weakest provider of control. If even one nation or state does not provide adequate control, a species can spread and cause damage to all. This argues for a coordinated response among affected parties, both the sources and recipients of the invasive species.

Shogren (2000) addresses the issue of incorporating economics into risk reduction strategies for invasive species using a model of endogenous risk. The model represents the choices available to a policy maker regarding the allocation of resources to reduce the risk of invasive species by both mitigation and adaptation. Throughout the paper, the point is made that economics should be included in risk assessment to improve the effectiveness of such assessment. The study finds that a higher risk of invasive species increases adaptation, but the effect on mitigation depends on whether or not mitigation and adaptation are substitutes or complements. The paper does not provide any empirical examples.

Eiswerth and van Kooten, (2002) apply a stochastic optimal control model for invasive plant species given the uncertainty surrounding the ability to determine efficient management strategies for any given invasive species. Sources of uncertainty regarding relevant state variables include paucity of data, measurement errors, and substantial variability in intrinsic rates of spread. This means that invasions possess the properties associated with fuzzy sets and are thereby subject to analysis through fuzzy membership functions. They employ insights from expert panels to develop spread and damage estimates caused by invasive plants. Then, similar to Leung et al. (2002), they employ the stochastic dynamic programming model to identify economically optimal management choices from a portfolio of potential options with the results compared to those of a program that seeks to eradicate the invasive.

Moreover, Eiswerth and van Kooten apply their model on the decision making process of agricultural producers faced with harmful invasion of the weed, Yellow Star Thistle (YST).

Each producer wants to maximize the present value of future stream of net revenues. The expert panel focused on three potential agricultural land uses; grazing on rangeland, grazing on pastureland, and harvest of hay from pastureland. As the productivity of the land increases, the optimal weed management strategy gravitates toward options that are more expensive. By offering lower productivity, the optimal strategy is to apply chemicals, or to have no control at all. At the other end of the spectrum, it is optimal to apply more expensive technologies to irrigated pasture that affords both harvested hay and summer grazing. They conclude by stating that decision-making under uncertainty where experts can provide only linguistic descriptors of the growth of the invasive species and its potential damages can be beneficial when hard data are unavailable.

Empirical Cost and Benefits Estimates by Species

This section is organized by types of species, and for specific species within those groupings concentrating on Great Lakes. The groups are fish, crustaceans, mollusks, and aquatic/riparian plants.

Fish

Pimentel et al. (2001) report that a total of 138 non-native fish species have been introduced into the United States, most taking place in states with warm climates such as Florida and California. He also state that 44 native species are endangered and 27 being negatively affected. The paper estimates that economic losses due to alien fish are approximately US$1 billion annually. This takes into account the estimated annual US$69 billion in benefits from sport fishing.

Sea Lamprey

The Sea Lamprey has caused great losses to the commercial and recreational fisheries of the Great Lakes as a parasite on native fish. Unlike many other Great Lakes invasives, it entered the Lakes naturally traveling from its natural range in the Atlantic through the St. Lawrence Seaway (Jenkins 2001). Control methods for lampreys include lampricide for larvae control, barriers, traps, and a sterile male release program (Great Lakes Fishery Comm. 2004). A number of estimates are available for the costs of lamprey control and prevention. The OTA report states that $10 million is spent annually for control, research, and another $10 million on fish stocking. Another estimate gives total control costs for annual control and monitoring of sea lamprey in the U.S. and Canada as $13 million (U.S. Invasives Species Council; Jenkins 2001). The U.S. GAO, based on a survey of seven states, estimated that 1999 expenditures on sea lamprey were $275,000 for New

York and $3 million for Michigan (GAO 2000). Lupi et al. (1999) report that Granular Bayer treatment, a lampricide, costs approximately $5 million per application in U.S. waters of Lake Huron. This same treatment in the St. Mary's River costs $4.2 million per application (Lupi et al. 2003). The costs for sterile male release are approximately $300,000 per year in Lake Huron (Lupi et al. 1999; Jenkins, 2001). Two other sources report on the benefits of control. The Great Lakes Fishery Commission reports benefits in the range of $2-4 billion per year (Sturtevant and Cangelosi 2000). Lost fishing opportunities and indirect economic impacts if control were terminated are estimated at $500 million annually (OTA 1993).

Ruffe

The Ruffe is another invasive fish, native to Europe that like the lamprey has invaded the Great Lakes. It is a predator on native fish and competes for habitat. Control includes toxins, trawling, and ballast water management. Estimated losses for the native fishery are estimated at $0.5 million annually (Jenkins 2001). For Lake Erie, between 1985 and 1995, Hushak (1997) estimated losses of $600 million for the sport fishery. Leigh (1988) evaluated the benefits and cost of a proposed Ruffe control program. The proposed program would control Ruffe using a pesticide also used on Sea Lampreys and would be used at river mouths at specific times of the year when Ruffe are concentrating in those locations. Control would occur over an 11 year period, at which time the population would be no longer a significant threat. Total costs for the control program would be $12 million with about 10%-20% variability depending on water level fluctuations in the rivers. The benefits of control are estimated based on the value of both commercial and sport fishery impacts over a 50 year time period. Without the control program, Ruffe populations are estimated to expand to all Great Lakes and to cause declines in walleye, yellow perch, and whitefish. Angler day values (1985) for Great Lake sport fishing were used as the basis of benefits for sport fishing and broken out between values for walleye and perch and all other fish except salmonoids. It was assumed that decreases in native fish populations would lead to proportional decreases in the number of angler days per year. Three scenarios were estimated, a minimum, moderate and maximum for fish population reductions. If fish populations occur right away, then annual benefits of the control program for both sport and commercial fishing varied between $24 and $214 million for the three estimates. Assuming that benefits accrue over the 50 year time period, and discounting benefits, the net present value varies between $105 million and $931 million. An estimated net public savings of $513 million could be achieved for the moderate scenario, primarily benefiting recreational fisheries.

Other Species

Other invasive fish include the Round Goby, which inhabits the Great Lakes and is a predator of benthic fauna. Currently there are no established controls for the goby but research is underway (Jenkins 2001). The mosquito fish has caused the declines of at least 15 native species in Southwestern desert rivers and springs (OTA 1993). The grass carp and common carp that were introduced to control aquatic weeds, have become a problem as they indiscriminately consume aquatic vegetation and destroy habitat for young native fish (OTA 1993). There are no known specific economic studies available for these species.

Crustaceans

Invasive crustaceans include the European Green Crab, the Mitten Crab, the opossum shrimp, and some species of crayfish. Estimates of costs attributed to the Green Crab are $44 million but it is unclear what those costs include (Licking 1999).

Mollusks

Pimentel et al. (2001) report that 88 species of mollusk have become established in the US. However, this number is based on the OTA study, which is over 10 years old.

Zebra Mussels are one of the best-studied and well-known aquatic invasive species. Originating from the Caspian Sea, they are assumed to have been introduced first to the Great Lakes via ballast water discharges. Now found throughout the Great Lakes and rivers of many states and Canadian provinces, Zebra Mussels colonize docks, locks, ship hulls, water intake pipes, and other mollusks and cause great damage to power plants and water treatment facilities. Controls include biocides, chlorine, thermal treatment, and mechanical/manual removal (Jenkins 2001).

There are many estimated costs for preventing, controlling, and studying Zebra Mussels. Unfortunately, the many estimates are not always reported in the same units which makes it somewhat hard for comparison. A number of reports and publications have reported that the costs of the mussel to be around $5 billion. A US Fish and Wildlife estimate as reported in Sun (1994) states that for a 10 year period (1990-2000) the costs in the Great Lakes will be in this range. This same estimate appears at least 4 other times and is presumed to be restatements of this original estimate (Anonymous, 1999; Jenkins 2001; Pimental et al. 1999; IMO 2001). However, another US FWS estimate puts the cost of damages over 10 years to intake pipes, water filtration equipment, and power plants at 3.1 billion (Cataldo 2001). Many of the cost estimates deal with the impacts on power plants and water treatment plants. OTA reports that the New York Seas Grant Extension Service estimated the costs of the Zebra Mussel to the power industry alone were as much as $800 million for plant redesign, and a further $60 million annually for maintenance. In addition, fouling by Zebra Mussels of cooling or other critical water systems in power plants can require shut down, costing as much as $5,000 per hour for a 200-megawatt system10 (OTA 1993). Armour et al. state that the net affect the US Great Lakes power plants (46) could be $100 million annually based on a one to two day downtime and a 1% reduction in plant heat rate. USGS estimates that annual control costs for hydroelectric plants are $83,000 per plant, for fossil- fuel plants $145,000, and $822,000 or nuclear plants (Anonymous 1999). One major power utility reported costs for 1991 of mussel monitoring at $100/megawatt of generating capacity (Jenkins 2001). O'Neil (1997) reports on a 1995 study of 35 states and 3 Canadian provinces that found the economic impact of Zebra Mussels to have total costs of $69 million, with a mean of $205,570 per facility (339 facilities surveyed). Nuclear power plants had the highest expenditure of $787,000 per facility, whereas fossil fuel electric generating stations had the lowest expenditure of $146,000 per facility. Annual expenditures were found to have increased between 1989 and 1995, from $234,000 to $17.8 million as the range of the mussels increased (O'Neill 1997). Sun (1994) conducted a similar study of Zebra Mussels on Lake Erie recreation. A travel cost model was estimated for Lorain County Ohio boaters. The results were presented at the Fourth International Zebra Mussel Conference in 1994, and appear preliminary. They are also contradictory, in that both positive and negative impacts of the mussel on recreation seem to have occurred. Although the ideas and generic modeling framework do appear applicable to estimating the impacts of Zebra Mussels on recreation in Lake Erie, this particular discussion did not provide enough details to determine actual impacts.

Plants

Aquatic or riparian invasive plant species include Hydrilla, European Loosestrife, Eurasian water milfoil, melaluca, and salt cedar. Hydrilla blocks irrigation canals, enhances sedimentation in flood control reservoirs, interferes with water supplies, impedes navigation, and reduces the productivity of native fisheries. Similar impacts occur from water milfoil. (Jenkins 2001). Florida spends approximately $14.5 million each year on hydrilla control (OTA 1993). European loosestrife invades wetlands and endangers native plants and wildlife by changing the resident plant community and altering the structure and function of the wetland (Jenkins 2001). It is estimated that European loosestrife imposes $45 million a year in control costs and forage losses (Pimentel et al. 2000).

Conclusion

The most obvious point of the paper is that the literature is still in its infancy. There are few theoretical and even fewer empirical, studies dealing with the economic costs of invasive species. The aquatic studies obtaining cost estimates reviewed above show values ranging from several hundreds of thousands of dollars a year to tens of millions of dollars a year. It seems apparent that a systematic approach is needed to develop a consistent method to estimate such costs.

The second point the paper illustrates is the difficulty involved in obtaining such an estimate. Determining economic costs of environmental concerns is no easy task under the best of circumstances. Human health values use values, existence values, valuations of ecosystem services are all issues environmental economists struggle with every day. The unique circumstances surrounding invasive species add a level of complexity to the task that increases difficulties involved in such valuations at a geometric rate. Besides the common measurement problems and lack of observable data, measuring the economic costs of invasive species involve determining rates of biological propagation, which do not always conform neatly with economic metrics (such as years or states). There are also the difficulties associated with assessing the risks of invasives. It is a difficult task how to estimate the benefits associated with controlling such a process. These issues combine to make policy options difficult to both formulate and evaluate new policies. As the literature points out, invasive species and their control have definite public good aspects and thus call for some level of government intervention. However, to what extent and what form that intervention takes place depends on numberless issues associated with both the region and the species involved. Optimal policy appears to be as unique as the individual species or ecosystem it is attempting to control and protect.

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