Final Report

to the

Prince William Sound
Regional Citizens' Advisory Council

Marine Invasive Species Program

Contract No. 952.11.04
FINAL REPORT: July 19, 2011 – July 31, 2012
Submitted July 31, 2012

Project Overview

Non-Indigenous Species (NIS) may specifically be classified as invasive when ecologically or economically damaging and/or causing harm to human health. We see the economic consequences of invasions in other states and regions. Alaska has not experienced significant impacts to date but examples tell us it may only be a matter of time, and all the more assured if we do nothing or little to prevent and mitigate invasions. To date, we as a state have not undertaken an economic assessment to estimate how severe an economic impact could be due to marine invasive species. Without this economic analysis the environmental arguments supporting action for an Alaska Council on Invasive Species become mute. There may be impacts, there may be environmental consequences, but a louder voice echoing the economic impacts may be required to get the ear of the Legislature. To this end we proposed to work in collaboration with the University of Alaska Anchorage's Institute of Social and Economic Research (ISER) to assess economic benefits and costs of taking action versus no action on invasive species in Alaska. This project is a result of the Marine Invasive Species Workshop held in 2010 by the Marine Subcommittee of the Alaska Invasive Species Working Group. Workshop participants discussed the status of marine invasive species in Alaska, the state's invasive species policies and management, and the potential impacts of marine invasive species on Alaska's commercial, recreation, and subsistence economies. Workshop participants developed general recommendations and committed to specific near-term actions of which an economic assessment was one priority area.

Progress during Reporting Period July 2011 – July 2012

This project took place between July 2011 and July 2012. To completely fund the project, several contracts had to be aligned before we could close the contract with Prince William Sound Regional Citizens Advisory Council (PWSRCAC). As a result, while this award officially started

July 19th, it was not executed until September 15th. Once the award was granted, we issued the subaward to ISER in September. The final deliverables for the project include 1) a four-page Research Summary (Appendix A), 2) a journal article to be submitted to a peer-reviewed academic journal (Appendix B), and 3) a PowerPoint presentation developed for the Alaska State Legislature (Appendix C). The following activities describe the details of the project. Products that are related to this project, but were completed outside the terms of this contract and through other funding sources will be supplemented to PWSRCAC when available.

The first step of the project was to develop a list of agencies that have undertaken invasive species work in the state (Appendix D).We completed this portion of the research by searching the Committee for Noxious and Invasive Plant Management (CNIPM) and Alaska Invasive Species Working Group websites, invasive species conference attendees lists, and also by talking with agencies and organizations about their collaborations. The list changed over the course of the project and was more extensive than we originally envisioned.

We designed a data request for expenditures of agencies and organizations involved in the management of invasive species in Alaska (Appendices E and F). We pretested and refined the data request in collaboration with several representatives from federal and state agencies that were present at the 2011 CNIPM Conference in Anchorage, Alaska. We then connected with agencies and organizations by email and follow-up phone calls to gather the information. Specifically, we requested budget information from 2007 to 2011 on employment, personnel cost, hourly effort, expenditures on equipment and supplies, volunteer effort, source and recipient of funds spent, and targeted invasive species. We also asked respondents to provide detailed information by species, action taken, location, and aerial extent of the action. If budget amounts were unknown, we asked respondents to provide a best estimate. Specific methods of data collection are noted in the journal article (Appendix B). Because of the large number of

agencies and organizations involved in the management of invasive species in Alaska and the complexity of gathering historical data from multiple people, the data collection period took longer than we anticipated. We collected data from November 2011 through March 2012. Overall, we gathered data from 84 of the 112 people that were contacted among 64 organizations (11 federal, eight state, 20 non-profit, seven private, six tribal, and seven university departments, and four local governments), a 75% response rate.

We worked closely with ISER to discuss data organization and analysis. The results from the data request are summarized in the following bullets. Further details can be found in the Research Summary (Appendix A) and the journal article (Appendix B).

- Who paid for invasive species work in Alaska between 2007 and 2011? There was a total of approximately $29 million spent to manage invasive species during the data collection period, with an average of $5.8 million per year. The federal government supplied most of those funds (84%).
- Who has done the work? Federal agencies carried out most of the work to manage invasive species. Non-profit organizations and state governments (including Universities) subsequently followed federal agencies, and other groups including out-of-state Universities, local and tribal governments, and private contractors spent much smaller amounts.
- How are funds being distributed regionally? Funding has been highest for the Southcentral and Southwest regions of Alaska, although funding has increased steadily for Southeast Alaska over the past five years.
- What species types (and therefore ecosystems) did the funding target? Most of the funding went to terrestrial invasive species (41% terrestrial plants and 38% terrestrial

animals), however funds for aquatic and marine plants and animals did increase over the past few years.

- What actions have been taking place? The greatest actions taking place are for research, monitoring, and eradication.
- How have jobs and payroll changed over time? Employment, payroll, and volunteer efforts have increased during the data collection period.

This spring, we were invited to present the preliminary results for this project at the Kenai Peninsula Weeds Workshop on May 4th, 2012 held in the Seward Marine Center Rae Building (Appendix G). This gave us the opportunity to inform the audience about the research that they had participated in and also allowed us to receive comments from our peers about the project.

This study also required us to develop a comprehensive list of literature to support our research (Appendix H). While there is an extensive body of literature for evaluating the economics of invasive species, this study is the first to evaluate historical expenditures of invasive species in Alaska. Only a few models are available to evaluate the cost-benefit ratios of different management actions of specific species. These data from this study will help us to project potential future investment scenarios and support the development of models for emerging invasive species threats. This will thereby help to provide recommendations for best management practices for invasive species.

The national trends and this study suggest there will be ongoing investments to address research, monitoring, eradication, and other actions related to invasive species in Alaska. While the invasive species problem in Alaska is still in its infancy, the state is not immune to the problem. There has been an influx of invasive species in Alaska due to increasing human population, development, and commerce. There is also an increasing awareness and involvement

by the public. With increasing significance of the problem, coordination of resources will become more critical in the future. Because Alaska is in early stages of species invasions, our state has the opportunity for cost-effective solutions such as early detection and rapid response and coordination of statewide stakeholders through an organizing body.

In closing, early detection and rapid response (EDRR) are among the most effective ways for reducing the costs of invasive species over the long-term (Leung et al. 2002). Despite the importance of prevention and early detection, there are many cases where non-indigenous species cause no harm. Often, invasions resulting from the introduction of non-indigenous species are difficult to predict and in cases where introduced species cause no harm, resources could be wasted in preparing for an unlikely invasion event (Keller et al. 2007). It is important to note that while prevention is the first line of defense, not all invasive species are stopped by even the best prevention measures. EDRR increases the likelihood that invasions will be stopped but success cannot be guaranteed. Ecosystem conditions and species' characteristics determine whether a non-native species will establish itself in a new location and whether it will cause damage. Keller et al. (2007) suggest that quantitative risk assessment can aid in optimally allocating resources towards prevention and early detection of the most likely invaders (Leung et al. 2002, Keller et al. 2007).

The Alaska Natural Heritage Program's Alaska Invasiveness Ranking System offers a tool to help invasive plant species management through prioritization of threats (Carson et al. 2008; Nawrocki et al. 2011). This plant ranking system allows priorities for action on invasive plants to be determined qualitatively but lacks to include marine and freshwater invasive species. Also, in order to address varying risks and trade-offs inherent in any management decision on invasive species, a more complex quantitative valuation and decision tool is needed that identifies the

economically optimal allocation of resources between prevention and control measures. Consequently, with just a qualitative ranking tool, there is no mechanism to tell a resource manager whether it is less costly to society to wait and let the introduction of an invasive species spread and turn into an invasion or whether it is best to act right away and eradicate. In both cases, trade-offs are important to account for when measuring the benefits and losses associated with each management alternative. As a result of this historic cost analysis project, the Institute of Social and Economic Research will develop a risk and decision analysis tool that will incorporate some of the economic trade-offs at hand for five select invasive species including glove leather tunicate, western water weed, reed canarygrass, knapweed, and clover. This tool will be aimed at helping resource managers allocate limited resources towards those invasive species where management actions offer the highest benefit cost ratios, in other words, where action results in the “most bang for the buck.”

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Managing Invasive Species: How Much Do We Spend?

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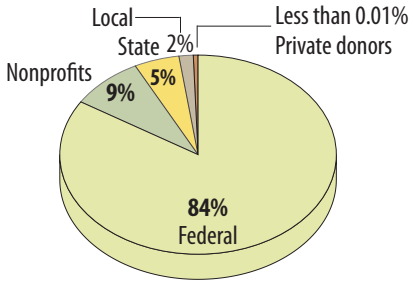
Institute of Social and Economic Research • University of Alaska Anchorage July 2012

Invasive species: they're along roadways and up mountain trails; they're in lakes and along the coast; chances are they're in your yard. You might not recognize them for what they are—plants or animals not native to Alaska, brought here accidentally or intentionally, crowding out local species. This problem is in the early stages here, compared with what has happened in other parts of the country. But a number of invasive species are already here, and scientists think more are on the way. These species can damage ecosystems and economies—so it's important to understand their potential economic and other effects now, when it's more feasible to remove or contain them.

Here we summarize our analysis of what public and private groups spent to manage invasive species in Alaska from 2007 through 2011. This publication is a joint product of ISER and the Alaska SeaLife Center, and it provides the first look at economic effects of invasive species here. Our findings are based on a broad survey of agencies and organizations that deal with invasive species.[1] The idea for the research came out of a working group formed to help minimize the effects of invasive species in Alaska.[2] Several federal and state agencies and organizations funded the work (see back page).

Figure 1. Who Pays to Manage Invasive Species in Alaska?
Total Spending, 2007-2011: $29 Million • Average Annual Spending: $5.8 Million



Source: ISER/Alaska Sealife Center survey, 2011-2012

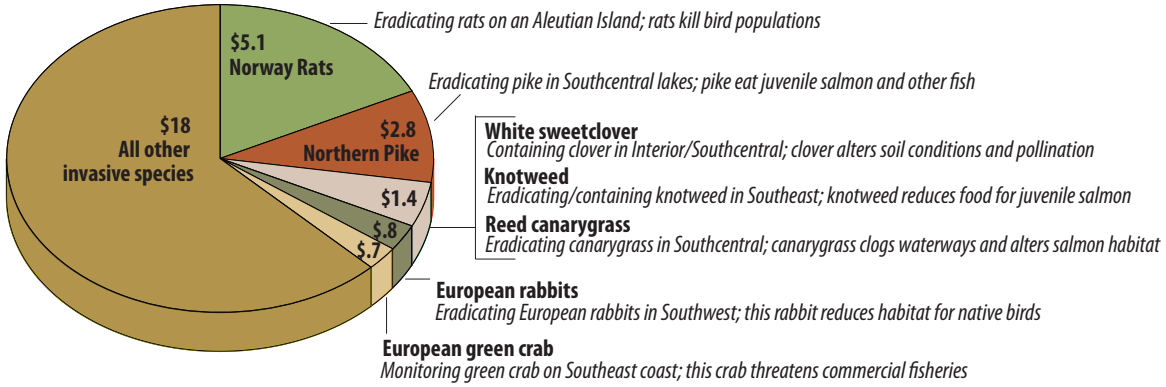
Who Paid?

Governments, nonprofits, and private donors spent about $29 million to manage invasive species in Alaska from 2007 through 2011, with an annual average of $5.8 million. The federal government put up most of the money—84%. Nonprofits and state and local governments supplied almost all the rest (Figure 1).

Which Were the Costliest Species ?

The biggest expenses were $5 million for eradicating Norway rats on an Aleutian Island where they had destroyed bird populations, and $2.8 million for killing Northern pike in Southcentral lakes; pike are voracious eaters of juvenile salmon and other fish. Nearly $1.5 million went for controlling a few damaging invasive plants. About $700,000 went for monitoring the European green crab, which is moving toward Southeast and threatening commercial fisheries (Figure 2).

Figure 2. What Were the Most Expensive Species to Manage, 2007 - 2011?
(In Millions of Dollars)



Source: ISER/Alaska Sealife Center survey, 2011-2012

APPENDIX A

What are Invasive Species?

Invasive species are non-native species that establish themselves, dominate habitats, and cause or are likely to cause economic loss, environmental damage, or harm to human health. These are primarily plants or animals that come from outside the state, but some—like Northern pike—are native in parts of the state but invasive when introduced elsewhere in Alaska.

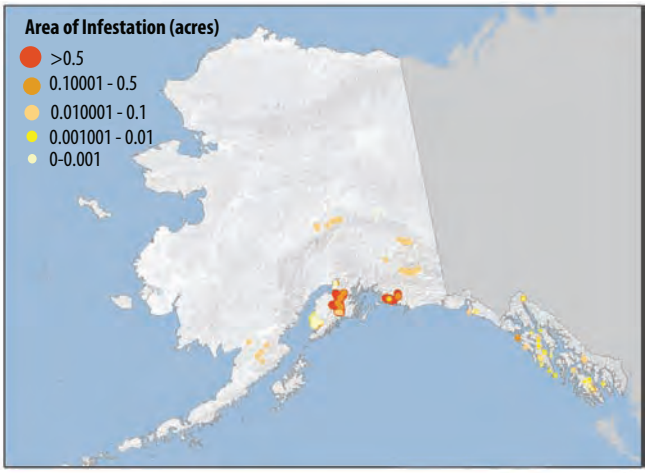
Some invasive species pose much bigger risks than others. Also, some non-native species aren't invasive and in fact benefit people. For example, non-native crops and livestock support the agricultural industry in Alaska and elsewhere.

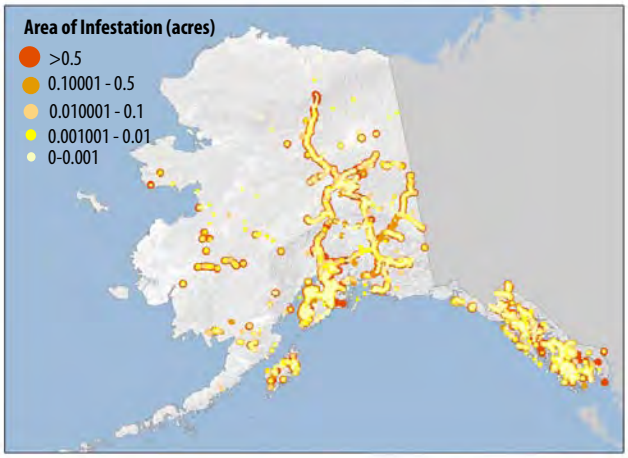
In 2007, there were 283 known non-native plant species and 116 non-native animals species (fish, amphibians, birds, mammals, invertebrates, parasites, and pathogens) in Alaska. Between 1968 and 2007, the number of known non-native plant species in the state nearly doubled. That means more than 10% of Alaska's 2,100 known plant species are non-native.[3]

Invasive plants have just recently begun to take hold in much of Alaska. Maps from the Alaska Exotic Plant Information Clearinghouse at the University of Alaska Anchorage (below) show how invasive plants spread just from 2000 to 2011. In 2000, known invasive plants were mostly confined to limited areas of Southeast and Southcentral Alaska. Ten years later, invasive plants were far more widespread in those regions and had reached into Interior and Southwest Alaska.

But in recent years there's also been more funding available for those who study invasive plants, so part of the reason for the sharp increase may simply be that the extra funding has allowed more observations of plants in more places. It's certainly likely that invasive plants are also in more remote areas of the state where they have yet to be observed.

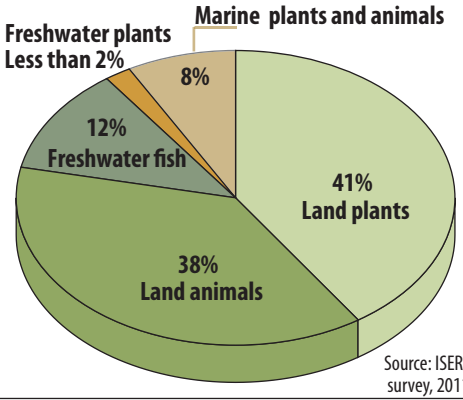
Spread of Invasive Plants, 2000 to 2011





Source: Alaska Exotic Plant Information Clearinghouse, UAA

Figure 3. Distribution of Spending to Manage Invasive Species in Alaska, By Type, 2007-2011



Source: ISER/Alaska Sealife Center survey, 2011-2012

Where Did the Money Go?

Figure 3 shows the distribution of spending for managing invasive species in Alaska, by type, from 2007 through 2011. More than 40% went for managing invasive land plants and another 38% for invasive land animals. As we discussed earlier, the biggest single expense for animals was for eradicating Norway rats.

Managing invasive freshwater fish accounted for another 12% of spending, but most was for eradicating a single species—Northern pike—in Southcentral Alaska, where it is invasive. In the Interior and the Arctic it is native.

Only about 8% of spending was for invasive marine life from 2007 through 2011. But big potential threats to Alaska's commercial fisheries have recently been identified, and spending to manage invasive marine plants and animals is likely to be up in the coming years. Those species include a dangerous marine animal called the glove leather tunicate (adjacent page) recently found in Sitka. It encrusts marine infrastucture and non-mobile marine animals like oysters and mussels, killing them. Another is the European green crab (adjacent page), which biologists fear could soon reach the Southeast coast of Alaska, threatening Dungeness and other native crabs.

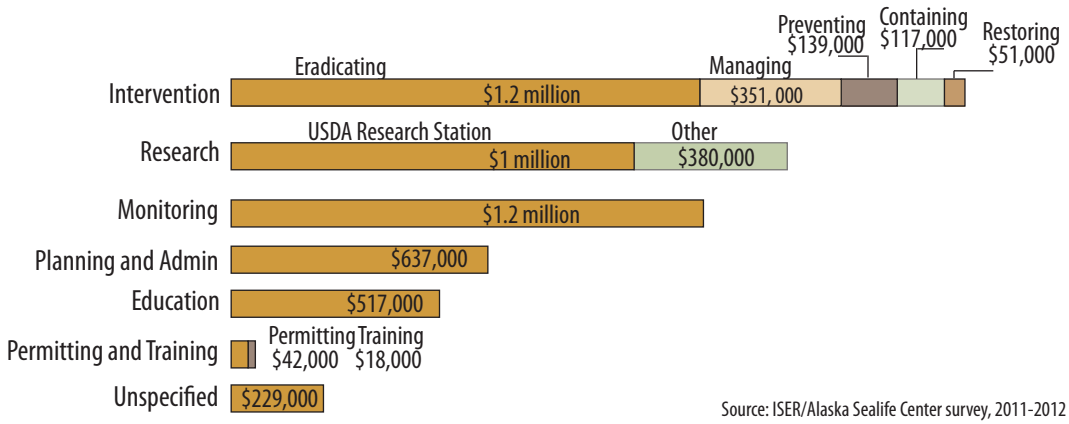
Northern pike (*Esox lucius*)
Photo courtesy of Alaska Department of Fish and Game

What Are the Management Actions?

There are a number of possible management actions for government agencies and nonprofits dealing with invasive species in Alaska. Figure 4 shows average annual spending for various management actions from 2007 to 2011.

• **Intervention**. About $1.9 million went to intervention activities annually. That included *eradicating* species considered very dangerous; *managing* them

Figure 4. Estimated Annual Spending, by Type of Action
(Annual Average, 2007 - 2011)



Source: ISER/Alaska Sealife Center survey, 2011-2012

to keep established invasions from spreading; *preventing* them from reaching the state; *containing* new invasions when they reached Alaska; and *restoring* ecosystems to their original state, after invasive species were removed.

• **Research**. About $1.4 million went for research annually. The U.S. Department of Agriculture's Agricultural Research Station in Fairbanks accounted for most research spending from 2007 to 2011. The station studied effects of invasive species on ecosystems, and also advised government agencies about ways to control invasive plants. It will close in 2012, due to federal budget cuts.

• **Monitoring**. About $1.2 million went to monitoring invasive species every year. Monitoring mostly tracks worrisome invasive species —like the European green crab—that may be finding their way to Alaska. It also includes monitoring species thought to be eradicated in Alaska, to make sure they are entirely gone.

• **Education.** Roughly $500,000 of annual spending from 2007 to 2011 was to make Alaskans more aware of the dangers invasive species pose.

• **Other Spending**. Several other kinds of spending support management of invasive species. That includes spending for planning and administration; for getting required permits; and training volunteers. Together, spending for those expenses averaged close to $700,000 annually in recent years.

European green crab *(Carcinus maenas)*
Photo courtesy of National Oceanic and Atmospheric Administration

Glove leather tunicate (*Didemnum vexillum)*
Photo courtesy of Alaska Department of Fish and Game

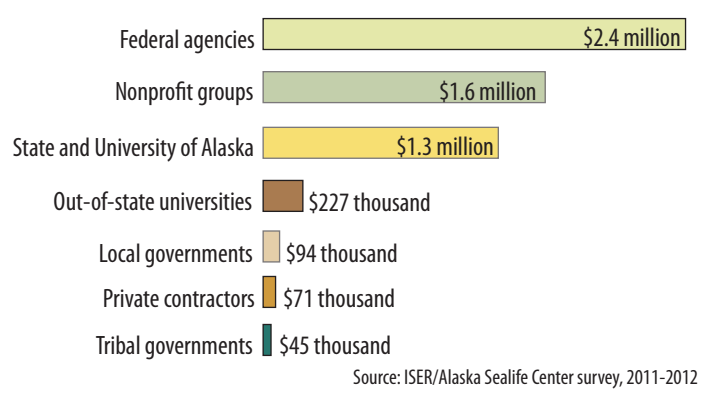
Who Does the Work?

Figure 1 on the front page shows who pays for managing invasive species in Alaska. But the agencies and organizations that put up the money don't always do the management work. Figure 5 shows which entities actually carried out the work and their average annual spending from 2007 through 2011.

Federal agencies spent about $2.4 million on an annual average. Nonprofit groups were next at $1.6 million, followed by state entities (including the University of Alaska) at $1.3 million.

Others—out-of-state universities, local and tribal governments, and private contractors—spent much smaller amounts.

Figure 5. Who Carries Out the Work?
(Annual Average Spending, 2007 - 2011: $5.8 Million)



Source: ISER/Alaska Sealife Center survey, 2011-2012

APPENDIX A
Jobs and Payroll

Managing invasive species in Alaska also generates jobs and payroll, as Figure 6 shows. During the study period, annual numbers ranged from 31 in 2007 to 73 in 2010. Payroll increased as job numbers went up, peaking at $3 million in 2010.

But job and payroll figures for 2010 and 2011 were boosted by one-time money from the federal American Recovery and Reinvestment Act, which Congress passed to help bring the U.S. economy out of recession. That money has now essentially been spent, so figures for 2012 are likely to be lower.

Volunteers have also become increasingly important in efforts to control invasive species, especially plants. For example, the Alaska Parks Foundation, Mat-Su Conservation Services, and other organizations coordinate volunteer efforts, and the National Park Service hires crews of students (at nominal pay). And it was a community-based monitoring program in Sitka—BioBlitz—that recently discovered one of the more dangerous invasive marine species, the glove leather tunicate (pictured on page 3).

Conclusions

We know that numbers of invasive species are increasing in Alaska, but that's a fairly recent phenomenon, and ways of dealing with the problem are still in their infancy. Because the problem is at an early stage—compared with other areas of the country—Alaska has opportunities to develop cost-effective solutions and create institutions to coordinate a multitude of stakeholders.

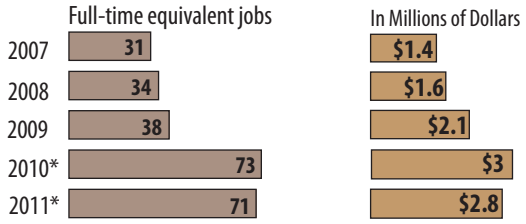
But the state government will need to take a bigger role in managing invasive species. We know that in recent years state funds made up only about 5% of spending, with the federal government supplying 84%. Federal spending cuts will close the Agricultural Research Station in 2012, and further cuts in federal money for managing invasive species seem likely.

Also, as the problem becomes increasingly important, coordinating limited resources will become more critical in the future. Yet several attempts in recent years—including proposed legislative action—have failed to establish a formal Alaska Invasive Species Council.

The bulk of funding so far has been targeted toward terrestrial plants and animals, although funds for marine organisms have increased slightly over the last few years. A shift toward more spending for marine plants and animals seems likely, as more species that pose threats to Alaska's commerical fisheries are being identified. Much of the spending to combat invasive species in recent years has been in Southcentral and Southwest Alaska, but spending in Southeast Alaska has steadily increased over the past 5 years, with the arrival of invasive marine species in Alaska waters.

Finally, our study found increased employment, payroll, and volunteer effort in dealing with invasive species—which may suggest that Alaskans are becoming more aware of this important problem.

Figure 6. Jobs and Payroll in Management of Invasive Species in Alaska



*The big jump in both jobs and payroll in these years is probably due largely to one-time money under the federal American Recovery and Reinvestment Act. Figures for 2012 will likely be lower.

Source: ISER/Alaska Sealife Center survey, 2011-2012

Endnotes

1. We e-mailed questionnaires (and followed up with phone calls) to 112 people at 64 organizations: 11 federal, 8 state, 20 nonprofit, 7 private, 6 tribal, 7 university, and 4 local government. We asked for budget information from 2007 to 2011 on spending related to invasive species—employment, personnel cost, hourly effort, expenditures on equipment and supplies, volunteer effort, source and recipient of funds spent, and targeted invasive species. We also asked respondents to provide detailed information by species, action taken, location, and aerial extent of the action. We collected information from 84 of the 112 people we contacted, for a response rate of 75%. We were especially careful to try to avoid double-counting spending in the complex web of agencies and organizations involved in managing invasive species.

2. In 2006, representatives of federal, state, university, and nonprofit organizations that deal with invasive species in Alaska created the Alaska Invasive Species Working Group, an informal organization with a number of goals, including coordinating resources and activities to improve management of invasive species and developing a statewide plan for managing invasive species. Group members hope to establish a formal council, but legislative action hasn't yet succeeded.

3. Carlson, M.L. and Shephard, M. 2007. "Is the Spread of Non-Native Plants in Alaska Accelerating?" In *Meeting the Challenge: Invasive Plants in Pacific Northwest Ecosystems*, General Technical Report GTR-694, U.S. Forest Service Pacific Northwest Research Station; and McClory J. and Gotthardt T. 2008. *Non-Native and Invasive Animals of Alaska: A Comprehensive List and Select Species Status Reports,* Final Report, Alaska Natural Heritage Program, UAA.

Reed canarygrass (*Phalaris arundinacea*)
Photo courtesy of Alaska Natural Heritage Program, UAA

Alaska SeaLife Center
windows to the sea

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Invasive Species Management Programs in Alaska – A Survey of Statewide Expenditures: 2007-2011

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Abstract

Invasive species are associated with the loss of biodiversity world-wide. Even though Alaska has remained relatively unaffected by non-native species for most of the 20th century, the influx of non-native plants shows that Alaska is not immune to the issue. With the problem in its infancy, Alaska can take advantage of cost-effective management given appropriate coordination, which to this date has not been established. This research collected data on statewide expenditures for invasive species programs between 2007 and 2011. Funding increased from $4.7 million in 2007 to $6.9 million in 2010, partly due to the American Reinvestment and Recovery Act. As in many other U.S. states, the main sources of funding (84%) were federal, with the remainder originating with non-profits (9%) and state and local governments (7%), cuts suggesting the state ought to take more ownership on the issue. The bulk of funding is targeted towards terrestrial plants and animals (79%), although funds have increased for marine and freshwater organisms over the past five years. During this period, the species with the largest expense included eradication of Norway rats from an Aleutian island ($5 million), eradication of Northern pike from salmon habitat in Southcentral Alaska ($2.7 million) and eradication of European rabbits affecting bird populations in the Aleutians ($0.8 million). Research (24%) and monitoring and eradication (both 20%) attract the most funding. The study also found increased employment, payroll, and volunteer effort which may suggest the invasive species issue in Alaska may show slightly increased public awareness.

Keywords: invasive species, Alaska, expenditure survey, resource management, ecological economics

Introduction

Invasive species are a growing threat and world-wide problem for the environment and the economy. Introductions of invasive species are sharply increasing, due in part to human population growth, global trade, commerce, and human development. The results of invasions include loss of ecosystem services such as reductions in water supply, loss of biodiversity, and production losses in agriculture and aquaculture to name a few. In many cases, the eradication of invasive species is impossible once they are established within the native ecosystem. In cases where there are environmental and economic damages associated, the costs to society of trying to keep the invasions at bay become recurring long-term costs (Perrings et al. 2002). The human dimension of the problem shows that solutions may be sought as much in economics as in ecology.

We define non-native species as those species that were introduced by people. In the Western Hemisphere, the definition is typically thought to mean those species brought to North America by Euroamericans in the last 300 years. Invasive species are those non-native species that establish and generally dominate habitats and whose introduction does or is likely to cause economic loss, environmental damage, or harm to human health. In contrast to our definition, some people would consider Alaska's native alder to be "invasive". We restrict the term invasive species to non-native species, such as white sweet clover *Melilotus albus*, that establish and cause ecological alterations.

Not all non-native species result in invasions and not all invasions have solely negative effects on human society. Many non-native species, invasive and non-invasive, are beneficial to humans. For example, the cultivation of non-native crops and non-native livestock are the backbone of the U.S. agriculture industry. Non-native plants and freshwater plants and organisms play an important role in the horticulture, ornamental plant, and aquarium markets. Thus, non-native species can be important to many industries. In Alaska, the invasive non-native species of white and yellow sweet clovers *Melilotus officinalis* in conjunction with honeybees were introduced by local beekeepers to boost local honey production.

The management of invasive species is an economic and policy issue and has less to do with the biology and ecology than many people realize (Perrings et al. 2002). It is primarily an economic phenomenon requiring economic solutions. These can take the form of either incentivizing changes in human behavior or developing institutions focused on finding solutions to the problem. Social science and especially economics provide important tools for decision making.

Economics can be used to understand the drivers of the invasive species problem, analyze the costs, inform decision makers about the benefits of a set of management actions, and analyze the creation of proper institutions to deal with the problem adequately. The high degree of uncertainty associated with the ecology of invasive species adds complexity to any form of analysis (Horan et al. 2002).

There are many studies that estimate the economic effects of invasive species, particularly related to forestry and agriculture where invasives have a direct impact on commercial products and the effects are quantifiable based on measurable production losses (Feare 1980; Leitch 1994; Hirsch and Leitch 1996). More difficult to estimate and less studied are the impacts related to ecosystem services and health. These studies are considering the economic effects of invasive species within the total economic value framework, which includes market and non-market values. Non-market values are related to public goods such as clean air or water, which are not traded in the marketplace. Benefits provided by nature are often undervalued in the market place where private decisions and stewardship may not accurately reflect their true value to society. Non-market valuation studies are able to show the consequences of the loss or impairment of ecosystem services for the economic well-being of the people affected by invasive species. Often the reasons for the lack of research relates to the large amounts of data required to establish scientifically sound ecological-economic linkages. In many cases, the methodologies that relate marginal changes in the environment to marginal changes in economic value still need to be established (Aylward and Barbier 1992).

Due to the challenges associated with estimating the economic impacts of invasive species, there is no national or regional comprehensive study estimating all costs to society for all invasive species. Internationally, Gren et al. (2007) estimated the cost of alien invasive species in Sweden to range between 1.5 billion SEK and 5 billion SEK which is equal to between $10 million and $34 million in 2012 dollars annually. Oreska and Aldridge (2011) estimate the financial cost of freshwater invasive species control in Great Britain to amount to between £26.5 and £43.5 million per year equal to between $41.5 and $68 million annually. Interestingly, among all invasive species in Great Britain, the one with the largest control costs is Western waterweed *Elodea nuttallii*, a freshwater weed that was recently discovered in three locations in Alaska.

In the U.S. there are a few studies that attempted to quantify the costs of invasive species. The U.S. Congress Office of Technology Assessment estimated the economic losses of 79

invasive species between 1906 and 1991 to amount to $160 billion 2012 dollars cumulatively (U.S. Congress 1993). Pimentel et al. (2005) estimated the annual economic cost of some of the approximately 50,000 invasive species in the U.S. to amount to at least $137 billion in year 2012 dollars, equal to about one percent of the U.S. Gross Domestic Product. This estimate includes measurable productivity losses, the cost of damages to infrastructure, and invasive species control costs. Since the monetary value of ecosystem services lost and the loss of biodiversity is not included in this estimate, the measure at best serves as an underestimate and the true cost of invasions is likely several times larger (Pimentel et al. 2005). To name a few examples, the above estimate includes $120 million in annual losses and control costs related to freshwater weeds, $49 million in control costs and forage losses associated with purple loosestrife, and $21 million in control costs and production losses related to other terrestrial weeds annually. But the estimate lacks for example the loss to society of a native species going extinct due to the invasion (Houlahan and Findlay 2004; Pimentel et al. 2005).

With expenditures of $824 million in year 2000, the Federal government has been the most important source of funding to address harmful invasive species (GAO 2000). Most federal funds – about 88% of the total – came from the U.S. Department of Agriculture (USDA) (GAO 2000). More than half of total federal funds were spent on prevention activities (GAO 2000). States have made much lower investments in fighting invasive species and investment levels vary considerably by state and year (GAO 2000). For example, in 2000 California and Florida spent more than $127 million and $87.2 million in state money respectively (GAO 2000). State governments of Hawaii spent $10 million, Idaho $5 million, and Maryland $2.8 million in 2000 (GAO 2000). In 2008, state agencies in Oregon spent $5.2 million in state funds for invasive species related projects (Creative Resource Strategies 2010).

On a statewide basis, there are a few reports that estimate the economic losses related to invasive plants. Leitch et al. (1994) estimated the losses related to knapweeds in Montana, South Dakota and Wyoming to amount to $14 million annually. Leafy spurge, an invasive plant affecting range lands, causes an estimated $42 million in losses in Montana alone (Hirsch and Leitch 1996). Most recently, the economic impacts of freshwater invasive species in the Great Lakes states cost households and businesses significantly over $100 million annually (Rosaen et al. 2012).

No economic analysis has been conducted to shed light on past and current investments to address invasive species in the state of Alaska. Current and future investments in managing

invasive species need to be viewed as conserving market and non-market values humans derive from healthy Alaska ecosystems at risk from invasions (Colt 2001). In this context, the project's objective was to collect data on direct management costs for the years between 2007 and 2011. The survey was conducted with federal, state, local, tribal, non-profit, and private agencies and organizations involved in invasive species management in Alaska. This approach allowed us to get a complete picture of the investments taken on all levels of government and citizens' involvement.

Invasive Species in Alaska

OVERVIEW

While Alaska has remained relatively unaffected by non-native plants for most of the 20th century, the state has recently experienced an influx of non-native plants related to an increasing human population, development, and commerce. Carlson and Shephard (2007) found that between 1985 and 2005, the number of invasive plant species collected and recorded in Alaska increased by 81%. In Alaska, 154 non-native plant taxa were known in 1941, 174 in 1961, and 283 in 2007, relative to a total of 2,100 known taxa in 2007.

The Alaska Exotic Plant Information Clearinghouse (AKEPIC) keeps track of known infestations in Alaska. Figures 1 and 2 show the extent of known terrestrial plant infestations in Alaska in years 2000 and 2011. The two maps show a dramatic increase in the known infested area over the last decade and shows predominately infestations along roads and human development because observation effort is higher for areas along the road system compared to remote areas of the state (AKEPIC 2012). Since observation effort is known to have increased in the last decade and the available data does not show where invasive species are absent, the maps shown are biased and likely understate the current spread of invasive plant species in Alaska. Despite the uncertainty and lack of absence data, the extent of infestations shown in Figures 1and 2 can be viewed as a conservative (minimum) measure of the extent of invasive plant species in Alaska. In addition, the map does not show the extent of invasive terrestrial animals, fishes, or marine invasive species, thus excluding potential dangerous threats to Alaska's commercial fisheries.

Fig. 1 Map of Alaska showing the year 2000 presence of invasive plants in Alaska as recorded by AKEPIC, with a few invasions larger than half an acre occurring in Southcentral Alaska, in addition to spotty invasions of up to half an acre in size in Southeast Alaska

Fig. 2 Map of Alaska showing the year 2011 presence of invasive plants in Alaska as recorded by AKEPIC, with extensive occurrence and dramatically increased acreage of invasions in Southeast Alaska and statewide along road corridors and larger road-less communities in rural Alaska

Figures 1and 2 show that Alaska is not immune against the influx and invasions of non-native species and that the problem may have grown exponentially over the last ten years. Carlson and Shepard (2007) compare the current infestation condition of Alaska with the infestation condition the lower 48 states experienced 60 to 100 years ago. The invasive species problem in Alaska is still in its infancy where the most effective action can be taken well before invasions reach critical thresholds at which eradication and control effort becomes very expensive (Figure 3). Taking action now rather than delaying it into the future provides a unique opportunity for Alaska to minimize long-term economic loss.

Fig. 3 Public perception of the invasive species problem in relation to abundance of invasive species along a logistic invasion trajectory illustrating that Alaska is at an early stage in the invasion process where there is a known lack of public perception

Early detection and rapid response (EDRR) are among the most cost efficient and effective ways for reducing the costs of invasive species over the long-term (Leung et al. 2002). Education is an important process driving EDRR and needs to strengthen links between the public, different levels of government, industry, and non-governmental organizations (Perrings et al., 2002). Despite the importance of prevention and early detection, there are many cases where non-indigenous species cause no harm. Often, invasions resulting from the introduction of non-indigenous species are difficult to predict and in cases where introduced species cause no harm, resources could be wasted in preparing for an unlikely invasion event (Keller et al. 2007). It is important to note that while prevention is the first line of defense, not all invasive species are stopped by even the best prevention measures. EDRR increases the likelihood that invasions will be stopped and eradicated but success cannot be guaranteed. Ecosystem conditions and species' characteristics determine whether a non-native species will establish itself in a new location and whether it will cause damage. Keller et al. (2007) suggest that quantitative risk assessment can aid

in optimally allocating resources towards prevention and early detection of the most likely invaders (Leung et al. 2002, Keller et al. 2007).

The Alaska Natural Heritage Program's Alaska Invasiveness Ranking System offers a tool to help invasive plant species management through prioritization of threats (Carson et al. 2008; Nawrocki et al. 2011). While this plant ranking system allows priorities for action on invasive plants to be determined qualitatively, it does not offer a quantitative framework that identifies the economically optimal allocation of resources between prevention and control measures. Consequently, there is no mechanism to tell a resource manager whether it is less costly to society to wait and let the introduction of an invasive species spread and turn into an invasion (requiring control action in the future) or whether it is best to act right away and eradicate. In addition, it is the only tool currently available and entirely ignores other invasive species like freshwater and marine invaders.

Because invasive species costs to society are closely related to the abundance of invasive species, costs to society closely follow the biological invasion curve in Figure 3. Consequently, prevention measures, if successful, are the most cost effective management action for economic and environmental reasons (Leung et al. 2002). The costs of managing invasive species rise rapidly as the species gain a stronger foothold in the ecosystem. After the establishment and naturalization phases, eradication may no longer be a possibility, and damage mitigation and control may be the only feasible policy response (Figure 3). Once the non-native species establishes itself in the ecosystem, control measures result in continued expenses and long-term costs to keep the invasions from developing into harmful pests with serious economic consequences and environmental degradation.

Just like costs to society, public awareness seems to also follow the invasion curve (Figure 3). The public may not be aware of an invasive species problem until it is almost too late for applying cost effective measures to fight the non-native species from turning into wide spread pests. Often, the large expense related to continued control of an invasive species seems to raise public awareness more than education and outreach could at an early stage of the problem (Figure 3). This disparity emphasizes the importance of outreach and education in Alaska now rather than later.

INSTITUTIONAL HISTORY

In Alaska, invasive species have been on people's radar since the early 1990s and action was starting to be taken in 2000 when the Presidential Executive order 13112 on Invasive Species called for increased coordination among federal and state agencies, established a National Invasive Species Council comprised of eight federal departments, created the Invasive Species Advisory Committee, comprised of diverse stakeholders, and directed the preparation of the National Invasive Species Management Plan. In 2000, the Alaska Committee for Noxious and Invasive Plants Management (CNIPM) was founded as an informal group of individuals representing agencies and organizations statewide. The CNIPM list-serve provides information on invasive plant issues statewide. The group looks for solutions to fight invasive plants in the state.

The Alaska Department of Fish and Game (ADF&G) in 2002 developed the Freshwater Nuisance Species Management Plan. The plan focuses on taking advantage of Alaska's early state in the invasive species problem, and as such focuses on prevention of invasions. Its main goal is coordination of prevention and monitoring efforts among the public, federal, state, local, and tribal governments, and the development of an effective public communications program. The plan further outlines the establishment of a coordinating council similar to the invasive species councils created by most of the lower 48 states. To this date, ten years after the goal of creating a council, steps have been taken to create this institution but legislation yet has to pass to formally establish it. A total of three former attempts to create an Alaska Council on Invasive Species by legislative action failed in 2007, 2009, and 2012. Recent invasions of Western water weed and the glove leather tunicate *Didemnum vexillum* suggest statewide coordination and prioritization is pre-requisite to managing resources effectively.

In 2006, the Alaska Invasive Species Working Group (AISWG) was formed by Memorandum of Understanding (MOU) among invasive species experts in federal, state, and local government positions. The group was established with hopes of becoming a formalized Alaska invasive species council in the future. The University of Alaska Fairbanks' (UAF) Cooperative Extension Service coordinates the group with funding through the Environmental Protection Agency (EPA). AISWG's mission is to minimize invasive species impacts in Alaska by facilitating collaboration, cooperation and communication among AISWG members and the people of Alaska. This MOU formed another step in creating an invasive species council but again, no formal coordinating body has been established.

The Alaska Northern Pike Management Plan was completed in 2007 and by 2009, could show the first successful eradication of Northern pike *Esox lucius* in three closed-system lakes, two in Southcentral Alaska and a series of ponds in Yakutat. Besides the efforts of resource management agencies in Alaska, volunteerism increasingly became a part of invasive species management with community-based monitoring playing an increasingly important role.

In 2010, the Marine Subcommittee of the AISWG held a workshop in Seward. This research is a result of that meeting during which the AISWG members and workshop attendees set as one of the priorities the need to conduct an economic impact study for Alaska (AISWG 2010). During a 2010 community-based invasive species survey, an unidentified colonial ascidian was found covering submerged lantern nets at an aquaculture site in Sitka, Alaska. It was later identified as glove leather tunicate. Several glove leather tunicate eradication attempts have been implemented throughout the world with varying levels of success. The ADF&G has developed a response plan for eradication of glove leather tunicate in Sitka.

The year 2012, also brought federal spending cuts to Alaska which resulted in the USDA's Agricultural Research Service (ARS) Alaska operations to close. This closure leaves Alaska without an important research facility dedicated to researching the effects of invasive species on native ecosystems.

Methods

We developed a data request for agencies and organizations involved in the management of invasive species in Alaska. The data request was sent out by email and included a word document and excel table to provide a flexible format for agencies to respond in (Online Resource 1). We pretested and refined this data questionnaire in collaboration with several representatives from federal and state agencies that were present at the 2011 CNIPM conference in Anchorage, Alaska. Specifically, we requested budget information from 2007 to 2011 on employment, personnel cost, hourly effort, expenditures on equipment and supplies, volunteer effort, source and recipient of funds spent, and targeted invasive species. We also asked respondents to provide detailed information by species, action taken, location, and aerial extent of the action. If budget amounts were unknown, we asked respondents to provide a best estimate.

Due to the complex web of federal, state, local, tribal, and non-profit organizations involved, we paid particular attention to where the money was coming from and where it was finally expended, often involving several pass through organizations. For example, federal

agencies are major funding sources for non-profit and state agencies, but also actively manage invasive species on the ground. By checking funding sources and sinks, we minimized double counting of any of the funds recorded and thus could come up with a distribution of funds being expended on invasive species in Alaska. The difficulty in gathering historical data is that some agencies and organizations were unable to obtain data for certain projects or did not have a detailed budget tracking system in place. Also, for some agencies/organizations, there was only one contact and for other agencies/organizations there were several contacts. If there were several contacts for one agency/organization and only half the contacts responded, it does not imply half the funds were accounted for because the individuals that did not respond may have made up for more or less than half of what was reported by the individuals that did respond. Thus, the estimates presented are rather conservative in nature.

On the basis of a list of 112 agency contacts, we collected information from 84 individuals for a response rate of 75 %. We contacted 64 organizations, including 11 federal, eight state, 20 non-profit organizations, seven private organizations, six tribal organizations, seven university departments, and four local governments (Online Resource 2). Due to the different accounting systems, not all organizations were able to provide the information in the format we requested. We dealt with this issue by setting the following conventions: For agencies and organizations with varying fiscal years, we recorded data that applies to each individual organization's fiscal year. Even though fiscal years among different organizations may not align accurately, slight differences average out over the five year data collection period. In cases where the initial funding organizations were not known, we allocated the entire budget among multiple sources.

For calculating the number of jobs associated with invasive species management in Alaska, we estimate the Full-time Equivalent (FTE) employment of part-time workers based on hourly effort data collected and the number of full-time positions reported. We dealt with lump sum amounts for multiple actions or types of expenses across multiple years or across categories by dividing the total lump sum amount reported by the number of actions, years, or categories, assuming equal amounts per action, year, or category of expense. Some agencies added a travel category for expense which was not part of the data request. Consequently, the travel category is likely underestimated. For volunteer hours, we stated them as recorded by respondents or we imputed the hours based on an eight hour work day and the volunteer days and number of

volunteers reported. At last, we conducted follow up phone calls with all contacts in the data collection period from November 2011 until March 2012.

Results

In this section we report budget information for the past five years in nominal dollars, not adjusted for inflation. We first show the different sources of funding available for invasive species efforts in the state, followed by how these funds are distributed by action implementing entities, species type, and type of management action. We then present analysis of the number of jobs and payroll associated with invasive species work over the past five years and the number of volunteers involved. Finally, we show how the annual invasive species funds are allocated among the five Alaska regions and how this allocation has changed over the past five years.

In years 2007 to 2011, the amount of available funds for invasive species related effort in Alaska varied between $4.7 million in 2007 and $6.9 million in 2010 (Table 1). Funding originated to 84% from federal, 9% from non-profit, 5% from state sources, with the remainder from local government and private donors. On an annual average, the federal government contributed $4.9 million, non-profit organizations expended more than half a million dollars each year, and the State of Alaska spent roughly $300,000 on average annually. Local governments expend approximately $100,000 per year on average statewide.

For the past five years, the top two funding organizations for invasive species related efforts in Alaska were the U.S. Fish and Wildlife Service (USFWS) with over $1.6 million dollars in distributed funding annually and the USDA with over $1.5 million annually. These two federal agencies provided almost half of the total funding for invasive species work in the state between 2007 and 2011. The Alaska Sustainable Salmon Fund provided almost $400,000 annually for invasive species related efforts statewide. The available funds were then distributed among state, local, tribal and non-profit organizations.

Table 1 Alaska invasive species funding by source, 2007-2011

In 2009, under the American Reinvestment and Recovery Act of 2009 (ARRA), the Alaska Association of Conservation Districts entered into a cooperative agreement with the U.S. Forest Service (USFS) to accept $1.14 million to implement the Alaska Invasive Plants Project. The purpose of this grant from the USDA was to oversee and coordinate invasive plant programs

via coordinator positions stationed in Soil and Water Conservation Districts throughout the state. The coordinators conducted invasive plant surveys, control, education, and outreach projects in their regions. In addition, the Alaska Natural Heritage Program conducted the second phase of the Alaska Invasiveness Ranking System, a tool to prioritize invasive species management.

Over the past five years, federal entities not only played the main role in funding other entities, they were also the main entities implementing management actions with annual operating budgets for invasive species totaling more than $2.4 million annually (Figure 4). Federal agencies were followed by non-profit organizations with over $1.6 million annually in operating budget for invasive species work, as well as state agencies including state universities with budget obligations of $1.3 million annually (Figure 4).

Fig. 4 Action implementing entities and five year mean operating budget, 2007-2011

Over the past five years, more than three fourth of all funding went towards invasive species in terrestrial ecosystems (79%), followed by freshwater ecosystems (14%) and marine ecosystems (8%) (Table 2). On an annual basis, the proportions of funds spent among marine, freshwater, and terrestrial ecosystems have changed somewhat with increasing funds going towards marine and freshwater ecosystems. This trend indicates a shift towards a more balanced approach across all ecosystems. The expenditures were focused on terrestrial plants (41%) and terrestrial animals (38%), with an increasing share going towards the marine ecosystem over the time period investigated. In 2007, the proportion of funds going to marine invasive species equaled 7% whereas in 2011 it was 17% of the total available funds. Freshwater invasive species issues received between 12% in 2007 and 2008, and 20% of total available funds in 2009. For freshwater ecosystems, the largest proportion of funds was spent on invasive freshwater fish, particularly the eradication of Northern pike in Southcentral Alaska.

Table 2 Alaska invasive species funding by species, 2007-2011

Some of the most costly invasive species in Alaska within the past five years include Norway rats *Rattus norvegicus* ($5 million), Northern pike ($2.8 million), European rabbit *Oryctolagus cuniculus* ($0.8 million), and European green crab *Carcinus maenas* ($0.7 million).

The costs and type of actions required to deal with each invasive species vary by species. The rats were introduced by a shipwreck to Rat Island where they decimated local bird populations requiring actions costing over $5 million over the past five years. More than 50% of the funds were used for eradication efforts followed by 33% for monitoring. Northern pike which were introduced by local anglers into lakes and streams in Southcentral Alaska required $2.8 million between 2007 and 2011. Even though Northern pike are native to some parts of Alaska, they have detrimental effects on local salmon populations in Southcentral Alaska. Sixty-seven percent of funds for pike were spent on monitoring while 12% were used for the eradication. Most (96%) of the $0.8 million going towards European rabbits were used for eradication.

Given the importance of commercial fisheries in Alaska, the threat of marine invasive species including the observed northward movement of European green crab may warrant increased investments in the area of marine invasive species in the future (Hines et al. 2004). Between 2007 and 2011, Alaska spent $0.7 million mainly on monitoring, research, and outreach.

Terrestrial plant species that required recent and costly action include white sweet clover and knotweed *Polygonum spp.* (both $0.5 million), and reed canarygrass *Phalaris arundinacea* ($0.4 million). White sweet clover was intentionally introduced to Alaska by beekeepers to enhance honey production but the plant is known to alter soil conditions and pollination patterns, and degrade natural grass land communities (Klein 2011). Over 71% of the spending on white sweet clover went towards control measures and research. We subdivided control actions into management actions which keep established invasions from spreading and containment actions which keep new invasions from further dispersal. Knotweed and reed canarygrass are both able to clog waterways and have negative effects on local salmon populations. In both cases more than 80% of the available funds were spent on eradication efforts. Also, an increasing proportion of funds were spent on freshwater plants, which shows that these invasive species have arrived in Alaska and will require more attention in the future as the recent discovery of Western water weed in Alaska suggests.

Statewide, most budget obligations go towards intervention and research. Between 2006 and 2011, the largest proportion – about 25% of invasive species funding – was spent on research. Research amounted to approximately $1.4 million annually, ranging between approximately $1.2 million in 2007 and $1.6 million in 2008 (Table 3). Monitoring efforts were the second largest obligation with approximately $1.2 million annually. Monitoring budgets have ranged between

$0.5 million in 2008 and almost $1.6 million in 2009 but recently have decreased to over $1.0 million in 2011.

Table 3 State-wide funding by management action, 2007 - 2011

Administrative and planning expenses amount to between approximately $280,000 and $800,000 annually, or between 11% and 17% of total available funds (Table 3). Administrative expenses seem to have stabilized at approximately $700,000 annually in recent years. It is interesting to note, permitting requires approximately 1% of the total funding annually. Among all management actions, education and outreach received an increasing amount of funding with $290,000 in 2009 (7% of available funds) and more than $700,000 in 2010 and 2011 (13% of available funds) in that year. In regards to fostering public awareness early on in the invasion process, this trend seems to be an appropriate direction for Alaska (Figure 4).

All intervention actions (i.e. prevention, containment, restoration, management, and eradication) combined amounted to a third of all invasive species obligations over the last five years, totaling more than $1.8 million per year. Eradication, which destroys and removes new invasions, accounted for the third largest expense overall with more than $2.5 million spent on Norway rats alone in 2008, a fifth of total obligations. In addition, more than $350,000 annually are spent on management measures, keeping established invasions from spreading, followed by prevention ($139,000/year), which stops introductions, and containment ($117,000/year), which stops new invasions from spreading. Investments related to attempting to restore ecosystems to their initial state after removing invasions amounted to $50,000 annually, 1% of total budget (Table 3).

The survey we conducted also collected data on each individual organization's operating budget for invasive species, the number of jobs, and payroll associated with positions focused on invasive species actions in the state. The organizations with the largest annual operating budgets for invasive species related efforts include the USFWS ($1.1 million annually), USDA ($1.0 million), The Nature Conservancy (TNC) and the ADF&G (each $0.4 million).

Between 2007 and 2011, the number of jobs associated with invasive species efforts in Alaska increased from an estimated 31 FTE positions in 2007 to more than 70 FTE positions in 2010 and 2011. These jobs are mostly located in Alaska but include a few research positions

outside Alaska. Overall the payroll among all organizations for these positions amounted to $1.4 million in 2007, $1.6 million in 2008, $2.1 million in 2009, $3 million in 2010, and $2.8 million in 2011 for an annual average of $2.5 million and a total of almost $11 million spent on payroll over the past five years. The USFWS on average has 33 part time positions and one full-time position dedicated to invasive species work. ADF&G has 15 part-time positions and one full-time person employed. USDA had 10 full-time positions which are defunded as of 2012. The Smithsonian Environmental Research Center has 10 part-time positions. USDA had total payroll of $506,000 annually, Alaska Natural Heritage Program $288,000 annually, USFWS $207,000 annually, followed by the National Park Service (NPS) with $190,000 and ADF&G with $178,000 annually. Besides payroll, agencies reported costs for machinery to amount to between $202,000 and $1 million for an annual average of $440,000. The costs for equipment and supplies ranged between $429,000 and $872,000 annually for an annual average of $688,000.

Volunteer effort is an important aspect of community based monitoring, and control efforts for invasive species nationwide as well as in Alaska. Without the communities and their volunteers, many of the projects we collected data for would not have been possible to accomplish. It was in fact volunteers of a community-based monitoring program called a BioBlitz who discovered in Sitka one of the more dangerous marine invasive species, a colonial ascidian called glove leather tunicate. The number of volunteers involved in invasive species work in Alaska has increased in the last five years from around 200 in 2007 and 2008 to over 3,000 in 2011. This sharp increase is mainly due to funds being available for invasive species related work through the ARRA. Every year, the NPS hires crews of seven to nine students through programs with AmeriCorps or Student Conservation Association who provide supervision, transportation, equipment, and logistic support for “volunteer” crews pulling weeds in national parks. The crews receive small compensation and are considered “volunteers” by the NPS. Since ARRA made funds available to hire large crews, volunteer effort in 2010 and 2011 was unusually high with over 322,000 volunteer hours in 2010, and more than 100,000 volunteer hours in 2011. In comparison to other years, we estimate volunteer hours to range between 5,000 and 7,000 annually.

The Alaska State Parks Foundation reported 880 volunteers in 2011, up from 12 in 2009 and 513 in 2010, focusing on controlling invasive terrestrial and freshwater plants. Matanuska-Susitna Conservation Services reports more than 400 volunteers annually over the last three years. Despite the effect of ARRA, reports of increasing volunteerism from many other organizations

responding to our survey may indicate that public involvement and awareness is on the rise concerning the invasive species problem in Alaska.

We divide Alaska into five regions for the purposes of this funding analysis, North, Interior, Southcentral, Southwest, and Southeast. The allocation of available invasive species funding among the five regions in Alaska varies by year. Over the past five years, most funding went to efforts in Southcentral Alaska (43% of total), followed by Southwest Alaska (32%), and Interior Alaska (16%) (Figure 5). In Southwest Alaska, invasive species efforts cost on average almost $1.2 million per year (Table 4). Successful eradication efforts by the USFWS and the TNC concentrated on Norway rats, European rabbits, feral horses, hoary marmots, caribou, and Arctic foxes within the Alaska Maritime National Wildlife Refuge and other areas. As eradication efforts in the Alaska Maritime National Wildlife Refuge were completed in 2010, relatively fewer funds were expended in 2011 (Table 4).

Fig. 5 Annual invasive species funding by Alaska region, 2007-2011

More recently, invasive species efforts have increasingly focused on Southcentral Alaska with annual overall budgets of $886,000 in 2007 and over $2.2 million in 2011 for an annual average of almost $1.6 million (Table 4). One of the primary invasive species in Southcentral Alaska is Northern pike, which threatens salmon populations in Upper Cook Inlet. Primarily funded through USFWS and the Alaska Sustainable Salmon Fund, activities focused on monitoring, eradication, management, and outreach and amounted to more than $2.7 million over the past five years. In addition, $2.8 million was spent over the same time period to fight invasive terrestrial plants like orange hawkweed *Hieracium aurantiacum*, reed canarygrass, white sweetclover *Melilotus alba*, European bird cherry *Prunus padus*, and Canada thistle *Cirsium arvense*. Most funds for invasive terrestrial plants are originating from a diverse set of federal, state, and private sector sources with the highest proportion of funds spent on eradication and management of established invasions.

For the past five years, substantially less funding was received by the Interior, Southeast, and Northern regions of Alaska (Table 4 and Figure 5). In Interior Alaska, invasive species related work amounted to about $600,000 annually and concentrated on terrestrial plants like white sweet clover and European bird vetch *Vicia cracca*. As of recent, the Western water weed, which is

present in Fairbanks, Anchorage, and Cordova, has gotten increased attention by resource managers.

In Southeast Alaska, efforts during the past five years focused on marine invasive species due to the vicinity to British Columbia where many marine invasive species like European green crab and glove leather tunicate are already established. Consequently, local efforts are focused on monitoring activities amounting to approximately $350,000 annually (Table 4 and Figure 5). Such monitoring activities were successful in 2010 with the detection of glove leather tunicate in Sitka. In addition, Southeast Alaska saw successful eradication efforts for giant hogweed *Heracleum mantegazzianum*. Management efforts were conducted for stands of knotweed, orange hawkweed, and Canada thistle which were successfully removed but eradication could not be attained.

In Northern Alaska monitoring and research is occurring for invasive terrestrial plants along the Dalton Highway with expended funds of approximately $11,000 annually Table 4 and Figure 5). In Southeast Alaska, the presence of glove leather tunicate resulted in an increase in expenditures on marine invasive species over the last few years. The annual average amount of invasive species funding that is used statewide and not targeted on a particular region amounted to more than $1.9 million per year (Table 4). Over one million dollars of this amount was associated with the USDA's ARS located in Fairbanks. As a subject of federal spending cuts, ARS will close its Alaska operations in 2012. In the past, the ARS played a critical role in advising the USFS and Bureau of Land Management (BLM) on how to control invasive plants such as white sweet clover, orange hawkweed, and European bird vetch. ARS studied the effects of these invasive species on native ecosystems, operated the only cold climate seed bank in Alaska, and conducted a wide array of research concerned with food security (Fairbanks Daily News Miner, 2012).

Conclusions

This research offers insight to historic spending on invasive species in Alaska between 2007 and 2011. Given the observed trends nationally and as evidenced in this study we project ongoing investments to address research, monitoring, eradication and other actions related to invasive species in Alaska. During 2007 and 2011, total expenditures ranged between $4.7 million and $6.9 million annually with 84% of the available funds being provided through federal sources and only 5% originating as state funds. Compared to California, which in 2000 spent more than $127 million in state funds on invasive species, the relatively low investment level overall and particularly by the State of Alaska underlines the fact that the issue of invasive species is still in its

infancy in Alaska. The early stage of the problem offers an opportunity for cost-effective solutions like EDRR and the creation of formal institutions that are able to coordinate a multitude of stakeholders. There is a need for the state to take more ownership in regards to the problem, especially with federal spending cuts eliminating federal programs on invasive species in Alaska. Also, with an increasing importance of the problem, coordination of limited resources will become more critical in the future, yet after three failed attempts, establishing a formal Alaska Invasive Species Council has yet to be implemented.

The bulk of funding is targeted towards terrestrial plants and animals, although funds have increased slightly for marine and freshwater organisms over the last few years. The actions requiring the largest proportion of funding included research, monitoring, and eradication efforts. Invasive species work has been targeted in Southcentral and Southwest Alaska, although this has increased steadily for Southeast Alaska over the past five years with the arrival of marine invasive species in Alaska waters. The study also found increased employment, payroll, and volunteer effort which may suggest the problem of invasive species in Alaska is increasing and may result in slightly increased public awareness.

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Table 1

	2007	2008	2009	2010	2011	mean	%
Federal	4,264,000	5,973,000	4,252,000	5,441,000	4,385,000	4,863,000	84%
Non-profit	336,000	346,000	466,000	697,000	682,000	505,000	9%
State	82,000	112,000	407,000	614,000	327,000	308,000	5%
Local	25,000	127,000	126,000	114,000	121,000	103,000	2%
Private	13,000	13,000	55,000	26,000	30,000	27,000	<0%
Total	**4,720,000**	**6,571,000**	**5,306,000**	**6,892,000**	**5,545,000**	**5,806,000**	**100%**

Table 2

	2007	2008	2009	2010	2011	%
Terrestrial plants	1,712,000	1,858,000	2,041,000	3,521,000	2,710,000	41%
Terr. animals	2,272,000	3,635,000	1,932,000	1,988,000	1,144,000	38%
Freshwater fish	421,000	553,000	878,000	825,000	716,000	12%
Marine	248,000	451,000	373,000	487,000	800,000	8%
Freshwater plants	67,000	74,000	82,000	71,000	175,000	2%
Total	**4,720,000**	**6,571,000**	**5,306,000**	**6,892,000**	**5,545,000**	**100%**

Table 3

	2007	2008	2009	2010	2011	mean	%
Research	1,232,000	1,563,000	1,386,000	1,398,000	1,323,000	1,380,000	24%
Monitoring	1,470,000	498,000	1,569,000	1,241,000	1,081,000	1,172,000	20%
Eradication	202,000	3,261,000	611,000	1,076,000	663,000	1,163,000	20%
Admin./Planning	796,000	279,000	628,000	765,000	718,000	637,000	11%
Outreach	350,000	452,000	290,000	776,000	718,000	517,000	9%
Management	197,000	323,000	318,000	268,000	649,000	351,000	6%
Prevention	57,000	73,000	134,000	199,000	235,000	139,000	2%
Containment	293,000	39,000	73,000	114,000	68,000	117,000	2%
Restoration	26,000	33,000	53,000	78,000	65,000	51,000	1%
Permitting	37,000	31,000	44,000	77,000	23,000	42,000	1%
Training	24,000			12,000		8,000	0%
Not specified	36,000	19,000	200,000	888,000	2,000	229,000	4%
Total	**4,720,000**	**6,571,000**	**5,306,000**	**6,892,000**	**5,545,000**	**5,806,000**	**100%**

Table 4

	2007	2008	2009	2010	2011	mean	%
Southcentral	886,000	1,278,000	1,516,000	1,980,000	2,265,000	1,585,000	27%
Southwest	1,443,000	2,624,000	912,000	866,000	141,000	1,197,000	21%
Interior	510,000	703,000	821,000	688,000	277,000	600,000	10%
Southeast	98,000	305,000	352,000	379,000	606,000	348,000	6%
North			4,000	50,000	2,000	11,000	0%
Statewide	1,689,000	1,648,000	1,633,000	2,148,000	2,243,000	1,873,000	32%
Not-specified	94,000	13,000	67,000	781,000	11,000	192,000	3%
Total	**4,720,000**	**6,571,000**	**5,306,000**	**6,892,000**	**5,545,000**	**5,806,000**	**100%**

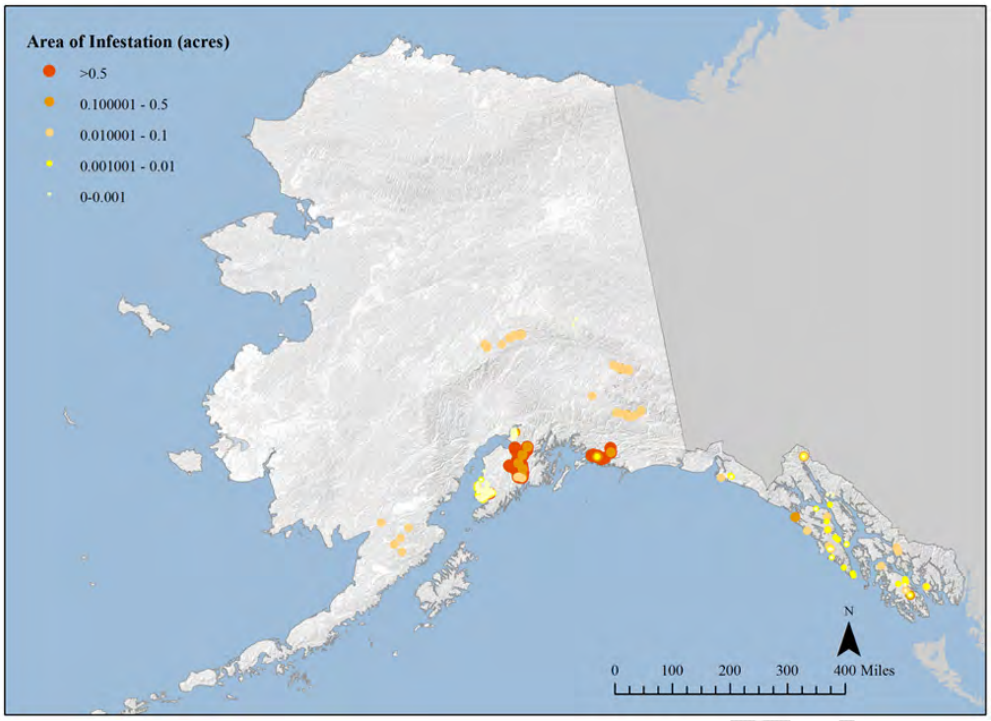

Figure 1

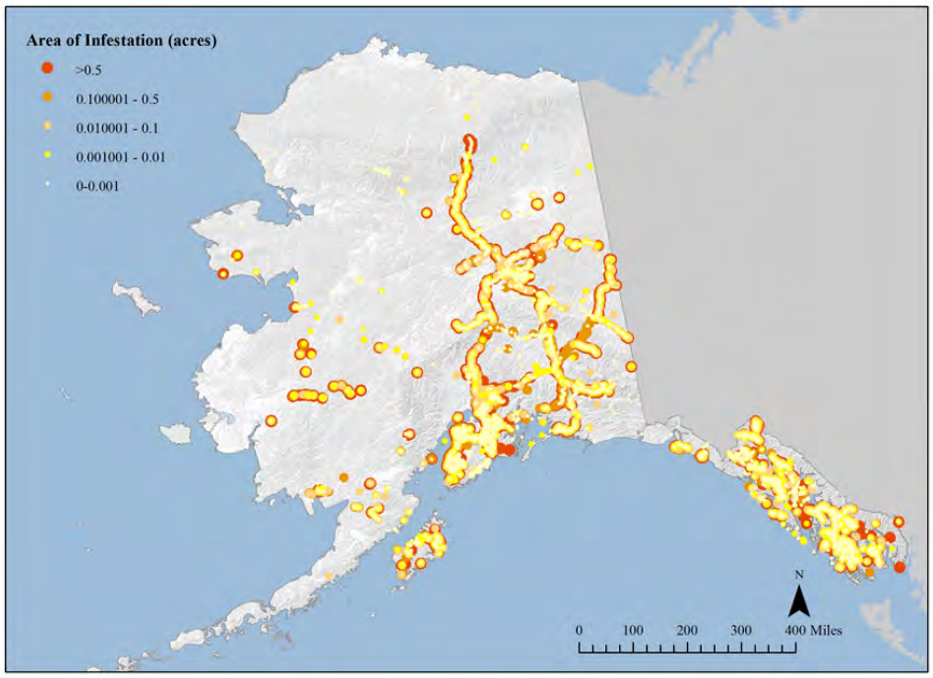

Figure 2

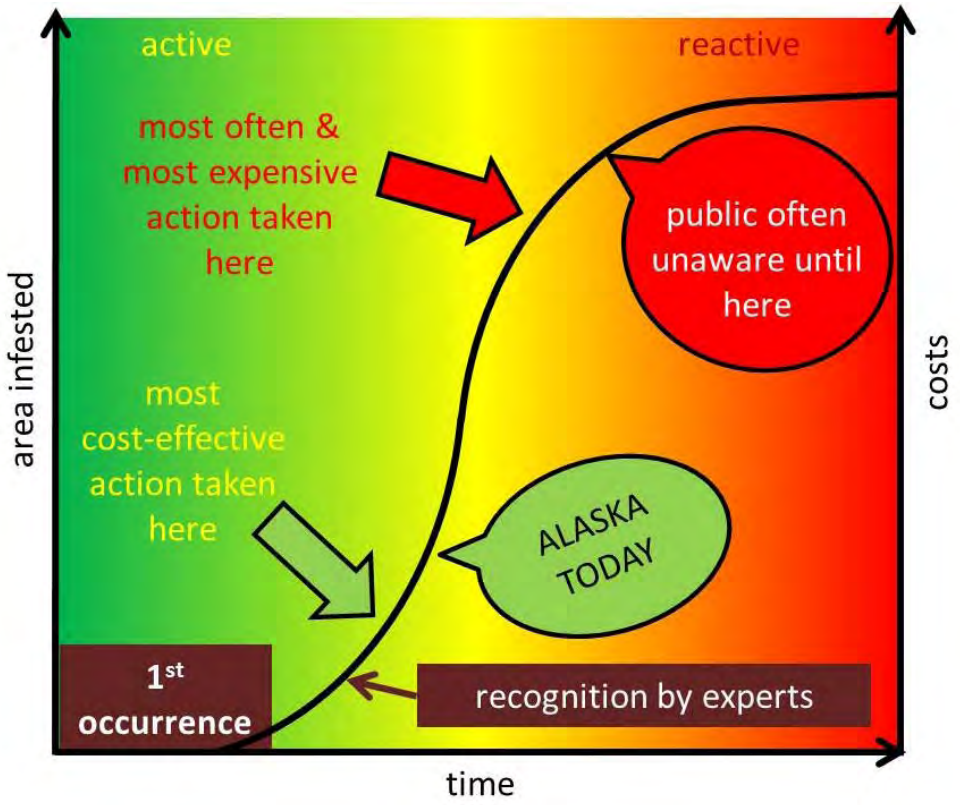

Figure 3

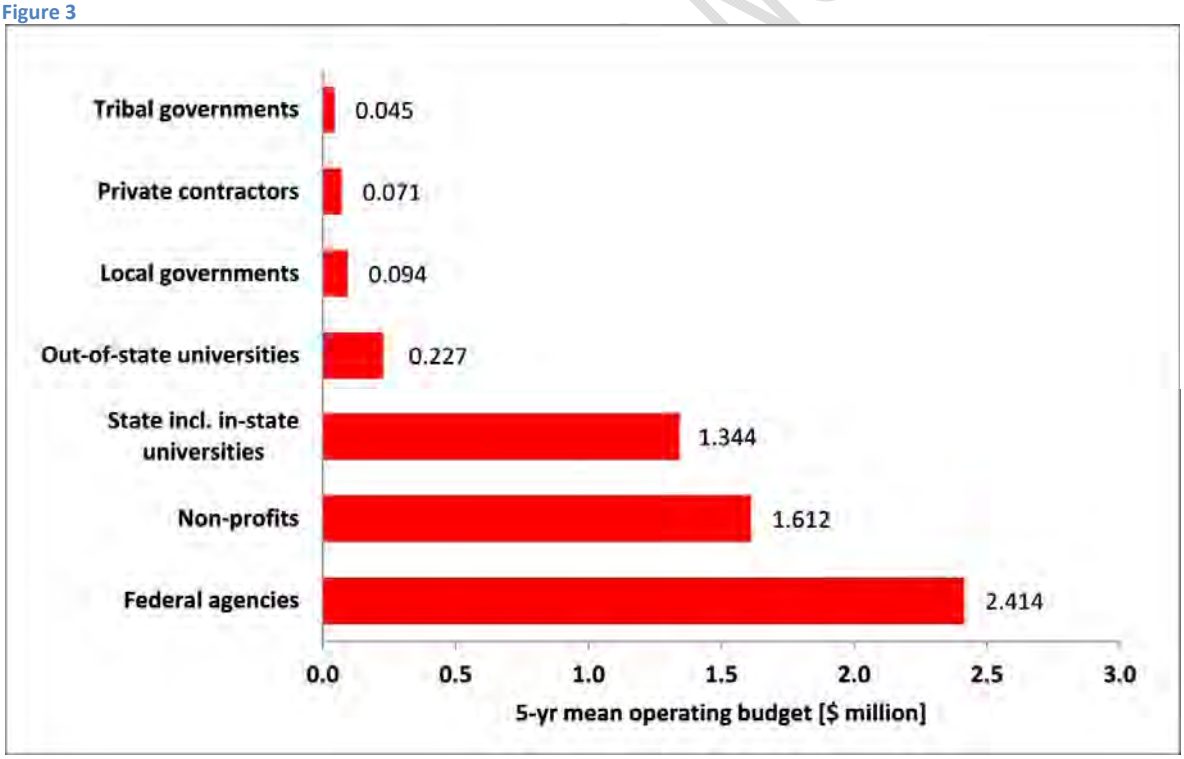

Figure 4

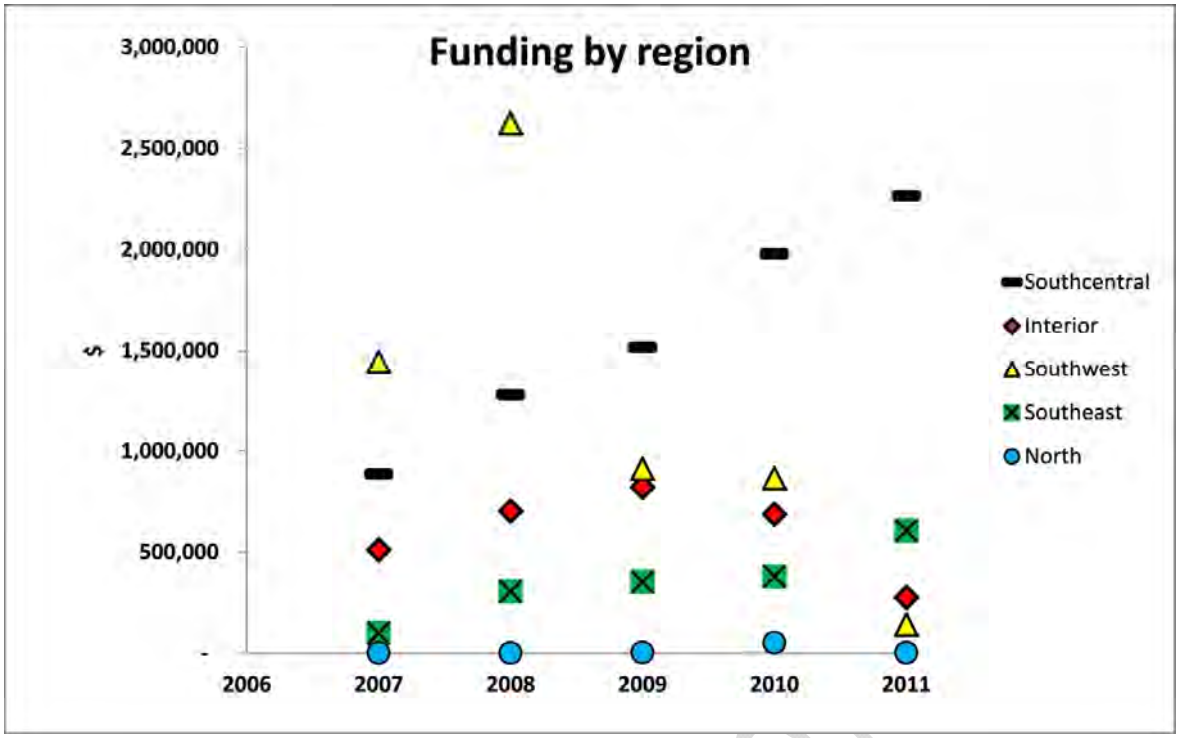

Figure 5

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Online Resource 1
Alaska Invasive Species Economic Impact Study – Data Check List

☐ **Your annual invasive species program's budget for the past five years (2007 – 2011):**

1. Budget (excel file or similar) for each year detailing:
2. Personnel:
    - Count of employees
    - Payroll
    - If available some measure of effort (labor hours, days, etc.)
3. Equipment:
    - Machinery, equipment rentals
4. Misc. supplies:
    - Herbicides, chemicals, office supplies, etc.
5. Volunteers:
    - Count of volunteers
    - Days annually where volunteers were present
    - If none applies, provide any other measure of volunteer effort
6. Amount of funding provided to other organizations:
    - Specify name of organization
    - Specify purpose of funding
7. List of invasive species you targeted that year

☐ **Additional information:**

- Specify "Actions" taken that year:
    1. Preparation of Permits or Environmental Impact Statements for proposed actions
    2. Intervention (specify as follows!)
        a. Prevention – stopping introductions
        b. Eradication – destroying/removing new invasion
        c. Containment – stopping new invasion from spreading
        d. Management – keeping established invasion from spreading
        e. Restoration – restoring ecosystem to initial state
    3. Monitoring
    4. Education / Outreach
    5. Research
    6. Other (specify!)

Please, continue next page!

Alaska Invasive Species Economic Impact Study – Data Check List

- Action budget amount
  - If unknown, try to approximate!
- Action species
  - Specify the invasive species
- Action location:
  - North, Southwest, Southeast, Southcentral, Interior
  - road system vs. remote
- Action area / action extend:
  - Total area treated (mile^2)
  - Stream length treated
  - Etc.
- Action success:
  - Provide some measure of success for the action in that year. This can be a qualitative or quantitative statement. For example, "eradicated, no re-growth for several years after treatment" or "density diminished by half"

Example for how you could provide the additional information:

Species name	**budget**	**Action (see list above)**	**Location**	**Area/extend of treatment**	**Measure of success**
Elodea	10% of annual budget	Eradication	Interior Fairbanks	5 square miles	Marginal success, Elodea came back one year after treatment
Green Alder Sawfly	$150,000	Monitoring	Southcentral	100 square miles	
…..	…	…			

Contact:

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Alaska SeaLife Center
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Annual Invasive Species Program/Efforts Budget						
		YEARS				
Category	**Description**	**2007**	**2008**	**2009**	**2010**	**2011**
Personnel	Count of Employees					
	Payroll					
	Measure of effort if available (labor hours, days, etc.)					
Equipment	Machinery, equipment rentals					
Misc Supplies	Herbicides, chemicals, office supplies, etc.					
Volunteers	Count of volunteers					
	Days annually where volunteers were present					
	If none applies, provide any other measure of volunteer effort					
Amount of funding provided to other organizations	Specify name of organization					
	Specify purpose of funding					
Targeted invasive species	List of invasive species you targeted each year					
* see also "annual actions" worksheet						

Annual Invasive Species Program/Efforts Action					
2007					
Species Name	**Budget**	**Action**	**Location**	**Area/Extent**	**Measure of Success**
2008					
Species Name	**Budget**	**Action**	**Location**	**Area/Extent**	**Measure of Success**
2009					
Species Name	**Budget**	**Action**	**Location**	**Area/Extent**	**Measure of Success**
2010					
Species Name	**Budget**	**Action**	**Location**	**Area/Extent**	**Measure of Success**
2011					
Species Name	**Budget**	**Action**	**Location**	**Area/Extent**	**Measure of Success**
* see also "annual budget" worksheet					

Key for Spreadsheet
Specific action:
EIS Statements or Permitting
Intervention - Prevention (i.e., stopping introductions)
Intervention - Eradication (i.e., destroying/removing new invasions)
Intervention - Containment (i.e., stopping new invasion from spreading)
Intervention - Management (i.e., keeping established invasion from spreading
Intervention - Restoration (i.e., restoring ecosystem to initial state)
Monitoring
Education/Outreach
Research
Other (please specify!)
Action budget:
if unknown, try to approximate
Action species:
Specify the invasive species
Action location:
North, Southwest, Southeast, Southcentral, Interior
road system vs. remote
Action area/extent (this will vary by action, but below are some examples of ways that you could report for each action:
Total area treated (miles squared)
Stream length treated
monitoring traps/plates used
people reached for Education/Outreach
Action success:
Provide some measure of success for the action. This can be a qualitative or quantitative statement (e.g., "eradicated, no re-growth for several years after treatment" or " density dimished by half")

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Online Resource 2

List of organizations and agencies contacted

Level	Agency/Organization: Division		Responses	Contacts
Federal	Coastal and Ocean Resources	Reported by another agency (n = 1 of 1)	1	1
	Department of Interior: Bureau of Land Management	Responded (n = 3 of 3)	3	3
	Department of Interior: Bureau of Ocean and Energy Management	Responded (n = 1 of 1)	1	1
	Department of Interior: National Park Service	Responded (n = 1 of 1)	1	1
	Department of Interior: USFWS (Alaska Maritime, Arctic, Becharof, Innoko, Izembek, Kanuti, Kenai, Kodiak, Koyukuk-Nowitna, Tetlin, and Yukon Flats National Wildlife Refuges and Anchorage, Fairbanks, and Juneau Regional Offices	Responded (n = 17 of 17)	17	17
	Environmental Protection Agency	Responded (n = 1 of 1)	1	1
	National Oceanic and Atmospheric Administration	Responded (n = 1 of 1)	1	1
	Pacific Services	Reported by another agency (n = 1 of 1)	1	1
	Pacific States Marine Fisheries Commission	Reported by another agency (n = 1 of 1)	1	1
	Smithsonian Environmental Research Center	Responded (n = 1 of 1)	1	1
	United States Air Force	Responded (n = 1 of 1)	1	1
	United States Coast Guard	No Response (n = 0 of 1)	0	1
	United States Department of Agriculture: Agricultural Research Service	Responded (n = 1 of 1)	1	1
	United States Department of Agriculture: Animal and Plant Health Inspection Service	Responded (n = 1 of 1)	1	1
	United States Department of Agriculture: Natural Resources Conservation Service	No Response (n = 0 of 1)	0	1
	United States Department of Agriculture: United States Forest Service	Responded (n = 2 of 5)	2	5
	United States Geological Survey	No Response (n = 0 of 1)	0	1
State	Alaska Department of Fish and Game	Responded (n = 3 of 3)	3	3
	Alaska Department of Natural Resources	Responded (n = 1 of 1)	1	1
	Alaska Railroad Corporation	No Response (n = 0 of 1)	0	1
	Alaska State Legislature	Some Response (n = 0.5 of 1)	0.5	1
	Alaska Department of Transportation and Public Facilities	Some Response (n = 2 of 4)	2	4
	California State Lands Commission	Reported by another agency (n = 1 of 1)	1	1
	Kachemak Bay Estuarine Research Reserve	Responded (n = 1 of 1)	1	1
	State Pathology Lab	No Response (n = 0 of 1)	0	1
Tribal	Alaska Intertribal Council	No Response (n = 0 of 1)	0	1
	Bristol Bay Native Association	Responded (n = 1 of 1)	1	1
	Council of Athabascan Tribal Government	No Response (n = 0 of 1)	0	1
	Ekuk Village Council	No Response (n = 0 of 1)	0	1
	Metlakatla Indian Community	Responded (n = 1 of 1)	1	1
	Sitka Tribe of Alaska	Responded (n = 1 of 1)	1	1

Non-Profit	Alaska Assocation of Conservation Districts: Soil and Water Conservation Districts (Fairbanks, Homer, Kenai, Kodiak, Salcha-Delta, Seward, and Upper Susitna; No Response from Anchorage, Juneau, Mid Yukon-Kuskokwim, Palmer, and Wasilla)	Responded (n = 7 of 13)	7	13
	Alaska Parks Foundation	Responded (n = 1 of 1)	1	1
	Alaska SeaLife Center	Responded (n = 1 of 1)	1	1
	Citizens Against Noxious Weeds Invading the North	Reported by other agency (n = 1 of 1)	1	1
	Coast Alaska	Reported by other agency (n = 1 of 1)	1	1
	Coastal and Oceans Research Institute	Reported by other agency (n = 1 of 1)	1	1
	Cook Inlet Aquaculture Association	Responded (n = 1 of 1)	1	1
	Cook Inlet Regional Citizens Advisory Council	Reported by other agency (n = 1 of 1)	1	1
	Copper River Watershed Project	Reported by other agency (n = 1 of 1)	1	1
	Juneau Watershed Partership	No Response (n = 0 of 1)	0	1
	Kenai Watershed Forum	Responded (n = 1 of 1)	1	1
	Mat-Su Conservation Services	Responded (n = 1 of 1)	1	1
	Prince William Sound Regional Citizens Advisory Council	Responded (n = 1 of 1)	1	1
	Prince William Sound Science Center	Responded (n = 1 of 1)	1	1
	Resurrection Bay Conservation Alliance	Responded (n = 1 of 1)	1	1
	Sitka Sound Science Center	Responded (n = 1 of 1)	1	1
	Southeast Alaska Guidance Association	Reported by other agency (n = 1 of 1)	1	1
	Student Conservation Association	Reported by other agency (n = 1 of 1)	1	1
	The Nature Conservancy	Responded (n = 1 of 1)	1	1
	Trout Unlimited	Reported by other agency (n = 1 of 1)	1	1
Local	City and Borough of Juneau: CBJ Jensen-Olson Arboretum	Responded (n = 1 of 1)	1	1
	City of Sitka	Reported by other agency (n = 1 of 1)	1	1
	Municipality of Anchorage: Department of Public Works	Responded (n = 1 of 1)	1	1
	Yukon Flats School District	Reported by other agency (n = 1 of 1)	1	1
University	Alaska Pacific University	Responded (n = 2 of 2)	2	2
	Portland State University	Reported by other agency (n = 1 of 1)	1	1
	San Francisco State University: Romburg Tiburon Center for the Environment	Responded (n = 1 of 1)	1	1
	University of Alaska Anchorage: Alaska Natural Heritage Program, Institute of Social and Economic Research, and Turf Department	Responded (n = 3 of 3)	3	3
	University of Alaska Fairbanks: Alaska SeaGrant Marine Advisory Program and Cooperative Extension Service	Responded (n = 2 of 2)	2	2
	University of Alaska Southeast: Landscaping (No Response from Mchapman)	Responded (n = 1 of 2)	1	2
	University of Washington	Reported by other agency (n = 1 of 1)	1	1
Private	Alaska Botanical Garden	No Response (n = 0 of 1)	0	1
	Alaska Garden and Pet Supply	No Response (n = 0 of 1)	0	1
	Granite Construction Co.	No Response (n = 0 of 1)	0	1
	Ground Effects Landscaping	No Response (n = 0 of 1)	0	1
	Kachemak Bay Shelllfish Hatchery	No Response (n = 0 of 1)	0	1
	MISC Contractors	Reported by other agency (n = unknown)		
	PWS Oyster farm and shrimp trawling on Perry Island	No Response (n = 0 of 1)	0	1
		Total	84.5	112
		Response rate	75%	

Supplementary Material Info Sheet

Journal: Biodiversity and Conservation

Title: Invasive Species Management Programs in Alaska – A Survey of Statewide Expenditures: 2007-2011

Author names and affiliations: Tobias Schwörer (corresponding author), Ecological Economist, University of Alaska Anchorage, Institute of Social and Economic Research, 3211 Providence Dr., Anchorage, AK 99508, Phone: (907) 786-5404, Fax: (907) 786-7739, Email: tschwoerer@alaska.edu; Rebekka Federer, Marine Invasive Species Program Manager, and Howard Ferren, Director of Conservation, both Alaska SeaLife Center, 301 Railway Ave., P.O. Box 1329, Seward, AK 99664

Supplementary material included:

Online Resource 1.pdf Alaska Invasive Species Economic Impact Study – Data Check List

Online Resource 2.pdf List of organizations and agencies contacted

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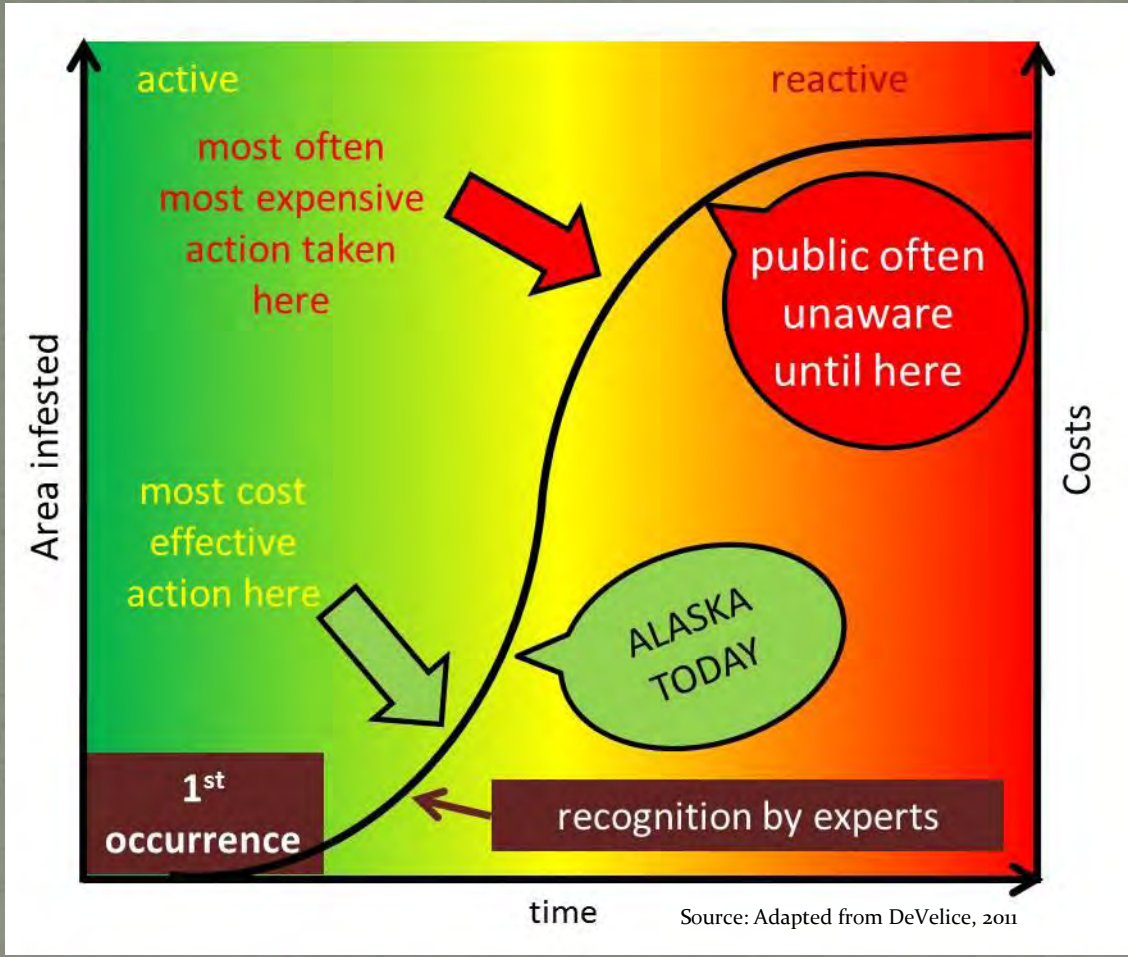
APPENDIX C

Investments in Statewide Invasive Species Management Programs in Alaska: 2007-2011



Source: Adapted from DeVelice, 2011

Tobias Schwörer, Economist
Rebekka Federer, Marine Invasive Species Program Manager
Howard Ferren, Director of Conservation

Overview

- Invasive Species - What's at stake?
- Invasive Species in Alaska
- Legislation and Actions in Alaska
- How the project came about?
- Need for Economic Study in Alaska
- Methods
- Data Analysis
- Summary
- Conclusions

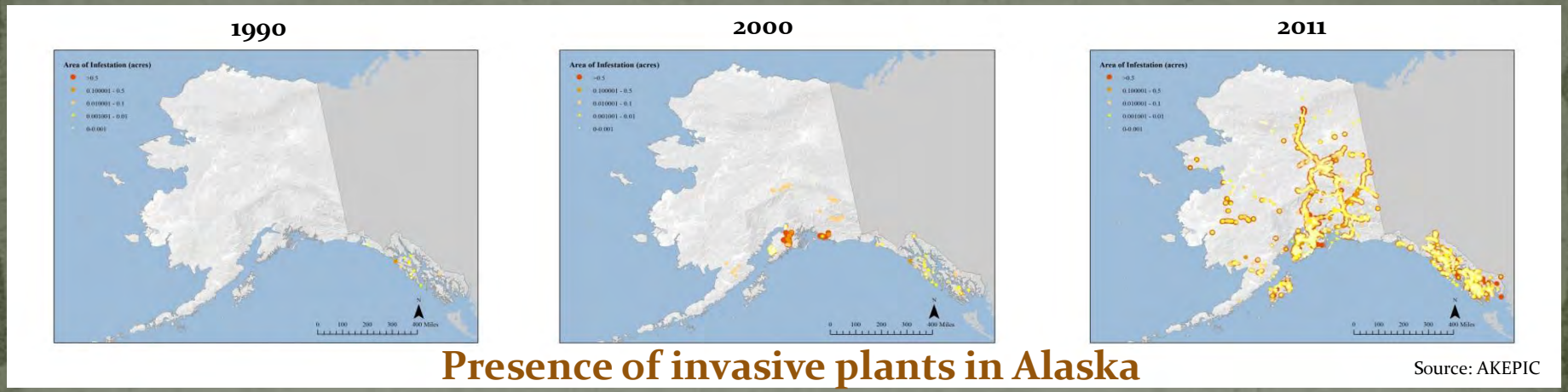
APPENDIX C

Invasive Species-What's at stake?

- "Invasive" = Non-native species 'whose introduction does or is likely to cause economic or environmental damage, or harm to human health' *(Federal Register 1999)*
- An economic and ecological problem
- Costs to U.S. society estimated at $137B/year *(Pimentel et al. 1999)*
- Effects on health; biodiversity loss; water supply, agriculture, commercial fishing, aquaculture, recreation, property values

APPENDIX C

Invasive Species in Alaska



Presence of invasive plants in Alaska

Source: AKEPIC

- Alaska not immune to invasive species problem
- Influx of non-native plants related to an increasing human population, development, and commerce
  - E.g.'s, 154 non-native plant taxa were known in 1941, 174 in 1961, 283 in 2007; Maps illustrate dramatic increase b/t 1990 and 2011 *(AKEPIC);* Number of invasive species collected and recorded b/t 1985 and 2005 increased by 81% *(Carlson and Shephard 2007)*
- The costs of managing invasive species rise rapidly as a species establishes in an ecosystem

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Legislation and Actions in Alaska

- 1990: Federal Non-indigenous Aquatic Nuisance Prevention and Control Act
- 1996: National Invasive Species Act
- 1997: Western Regional Panel established an advisory panel to the Aquatic Nuisance Species Task Force
- 1999: Presidential Executive Order 13112 on Invasive Species
- 2000: CNIPM founded
- 2001: 100th Meridian Initiative established
- 2002: ADF&G develops the Aquatic Nuisance Species Management Plan
- 2006: AISWG founded
- 2007: Alaska Northern Pike Management Plan completed
- 2008: Alaska House Resources committee sponsors HB 330
- 2009: Representative Johnson, Buch, Munoz, and Wilson sponsor HB 12
- 2009: First successful eradication of Northern pike from 3 closed lakes
- 2010: Quagga-Zebra Mussel Action Plan for Western US waters by WRP
- 2010: AISWG Workshop in Seward – recommended this study as a priority action
- 2010-2011: Found and identified *D.vex* in Whiting Harbor, Sitka, Alaska
- 2012: Development of *D.vex* response plan for Whiting Harbor
- 2012: USDA Agricultural Research Service closes due to federal spending cuts

APPENDIX C

How the project came about?

- Marine Invasive Species Workshop held by the Alaska Invasive Species Working Group (March 2010)
  - Invited outside experts from HI, WA, CA, BC, D.C.
  - Six key priorities and 11 near-term actions developed:
    - *Research and Development – Economic Impact Study*
    - Presentations and Workshop Report: http://www.alaskasealife.org/New/research/mis_workshop.php

APPENDIX C

Need for Economic Study in AK

- Estimate investments in statewide invasive species management programs
- Develop benefit-cost framework for select invasive species deserving further attention
  - Risk assessment / decision analysis tool
- Examine the investment value to establish an Organizing Body
  - *Workshop Priority and Near-Term Action Item: Management and Coordination – Invasive Species Council*
- Offer evidence to suggest whether or not there is a need to provide resources and direct managers to be more responsive

APPENDIX C

Methods

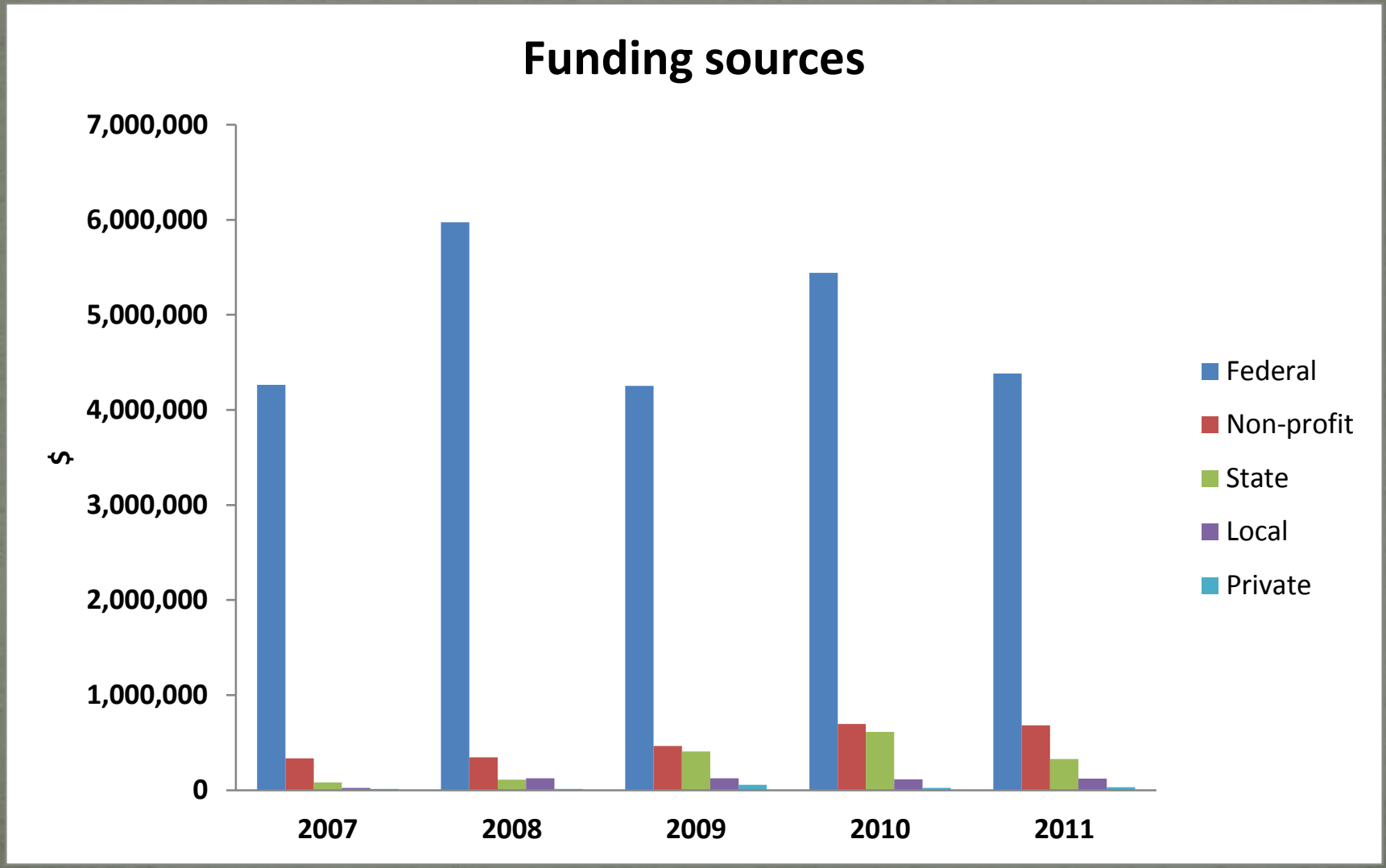
- Stakeholder survey of agencies/organizations (2007-2011):
  - federal, state, tribal, non-profit, local gov., private
- Data collection: November 2011-March 2012
- Variables:
  - Overall budget, payroll, employment, equipment, supplies, volunteerism, funding dispersal, action type, species type, location, etc.
- Of 112 agency contacts in 64 organizations, 84 individuals responded from 48 organizations (75% response)

Data Analysis

- Establish baseline data for costs of invasive species
- Analyze changes in investment levels over time
  - e.g., sources of funds, how money is dispersed, how and where money is used, species and ecosystems targeted, etc.

APPENDIX C

Sectors providing funding?



APPENDIX C

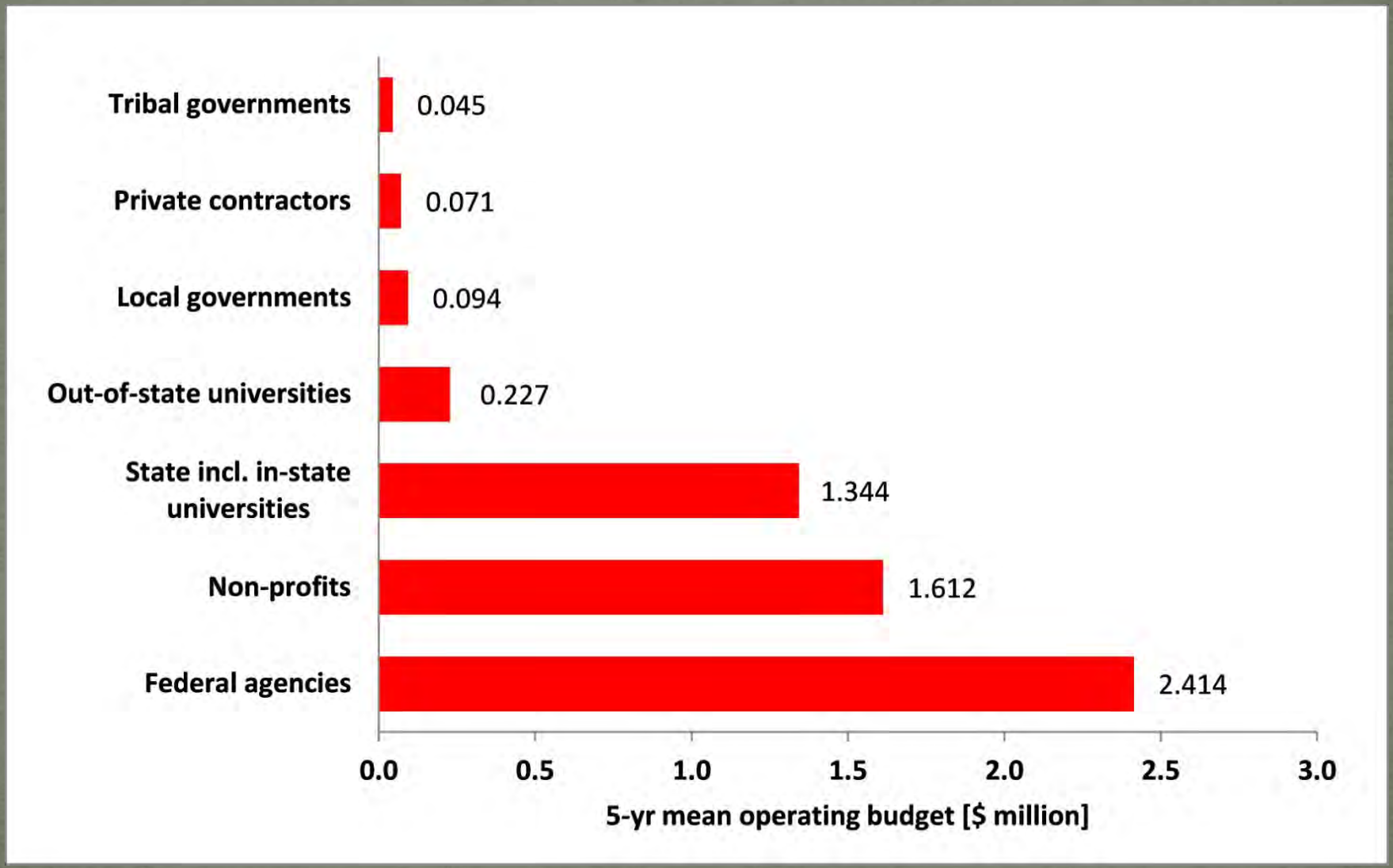
Sectors providing funding?

	5-yr mean
U.S. Fish and Wildlife Service	1,648,000
U.S. Department of Agriculture	1,509,000
Alaska Sustainable Salmon Fund	385,000
National Oceanic and Atmospheric Administration	270,000
National Park Service	216,000
Alaska Department of Fish and Game	186,000
Bureau of Land Management	156,000

	2007	2008	2009	2010	2011	mean	%
Federal	4,264,000	5,973,000	4,252,000	5,441,000	4,385,000	4,863,000	84%
Non-profit	336,000	346,000	466,000	697,000	682,000	505,000	9%
State	82,000	112,000	407,000	614,000	327,000	308,000	5%
Local	25,000	127,000	126,000	114,000	121,000	103,000	2%
Private	13,000	13,000	55,000	26,000	30,000	27,000	0%
TOTAL	**4,720,000**	**6,571,000**	**5,306,000**	**6,892,000**	**5,545,000**	**5,806,000**	**100%**

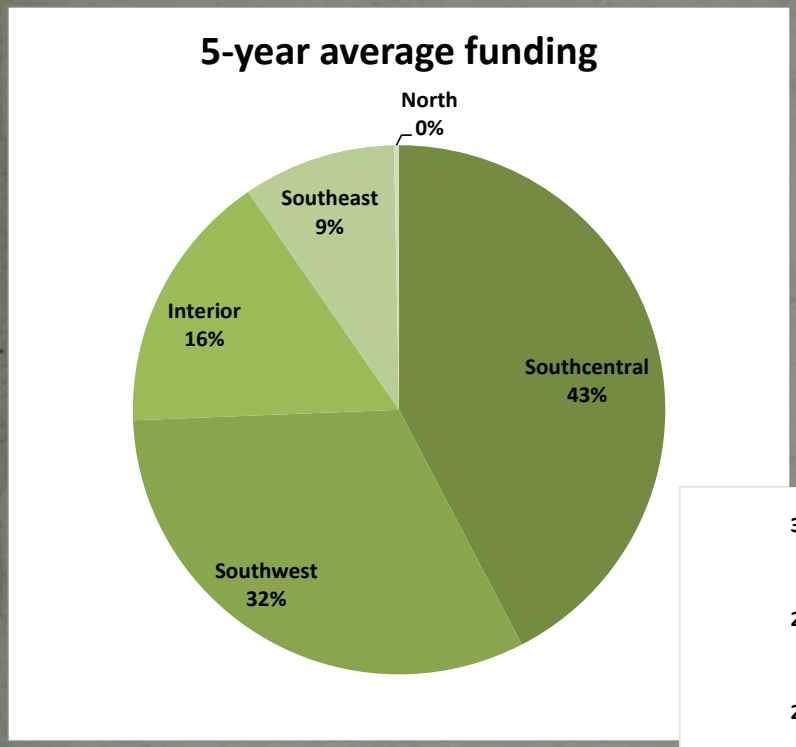
APPENDIX C

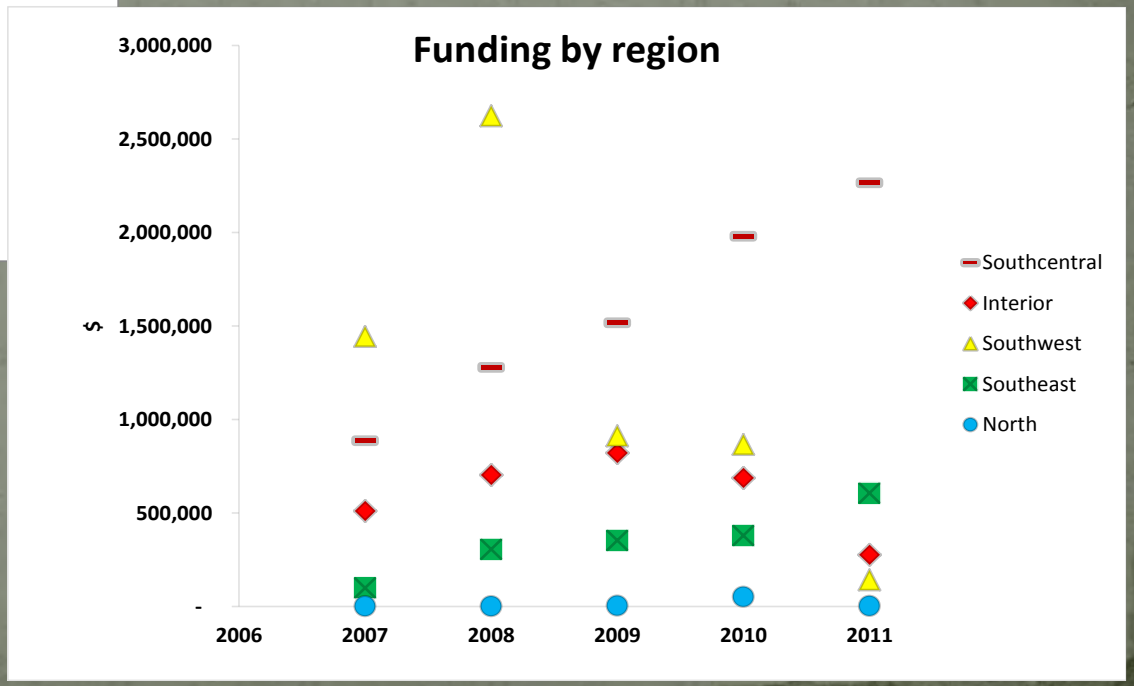
Who is doing the work?



APPENDIX C

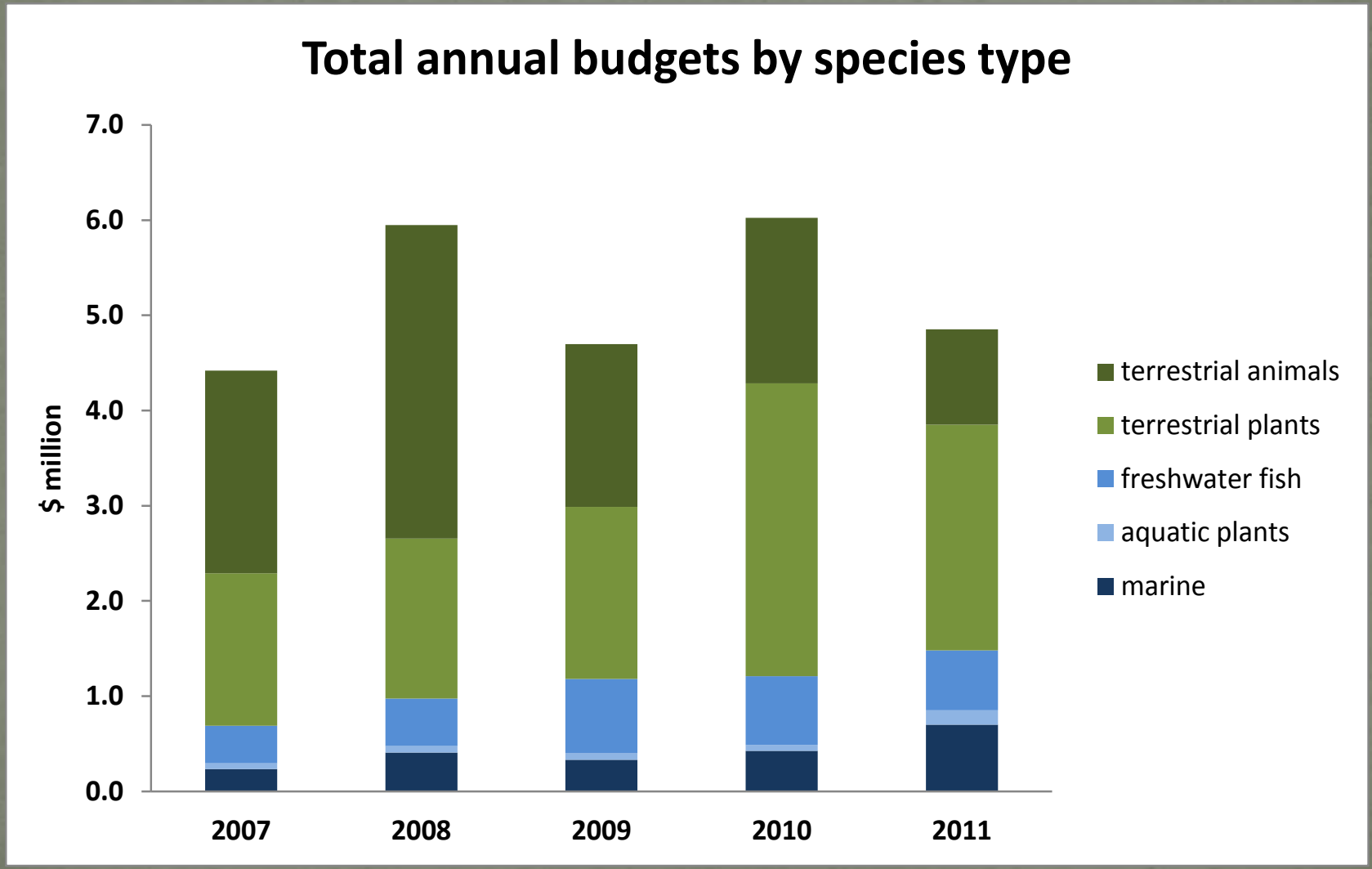
How are funds distributed regionally?





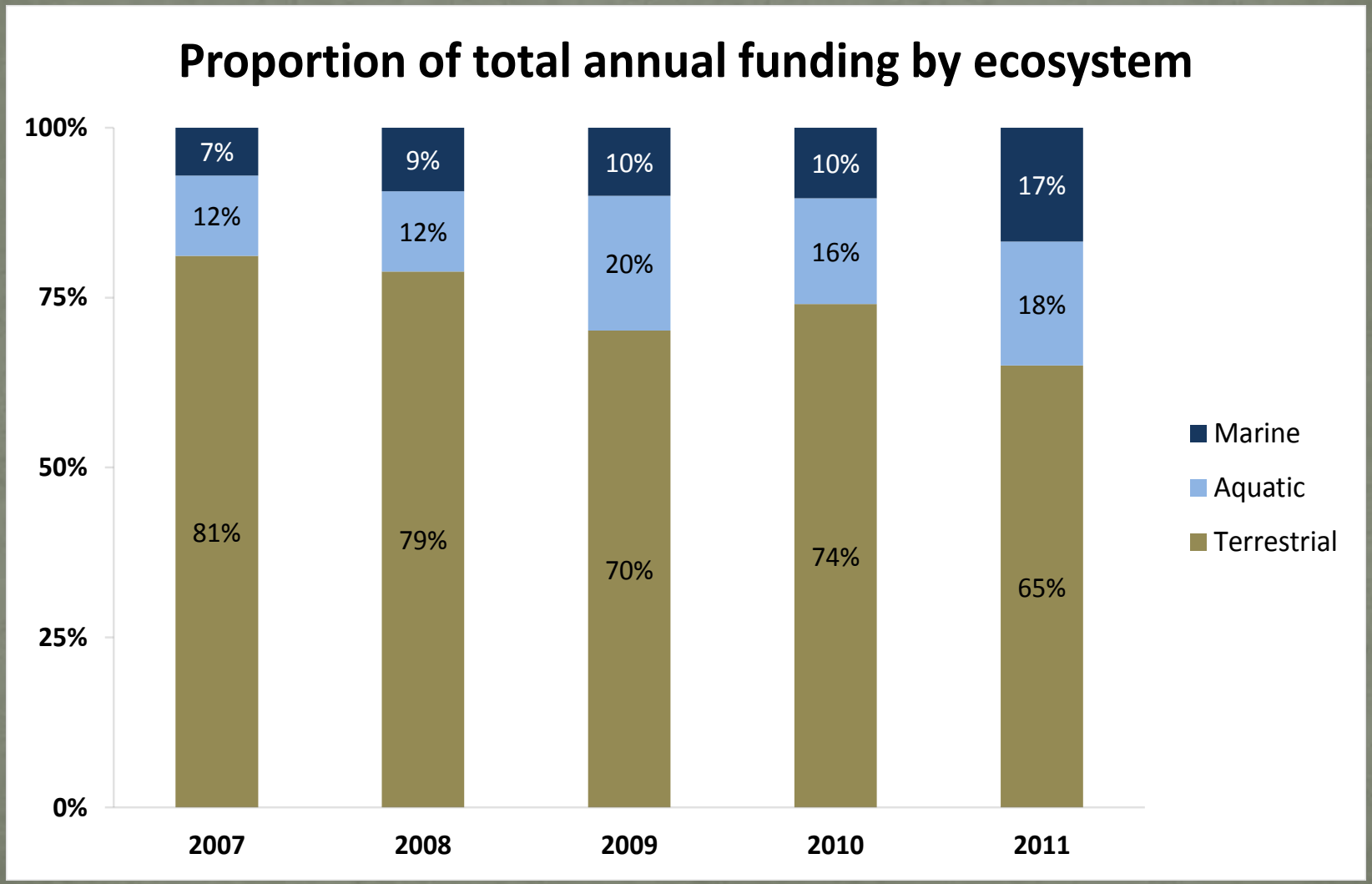
APPENDIX C

Species type being targeted



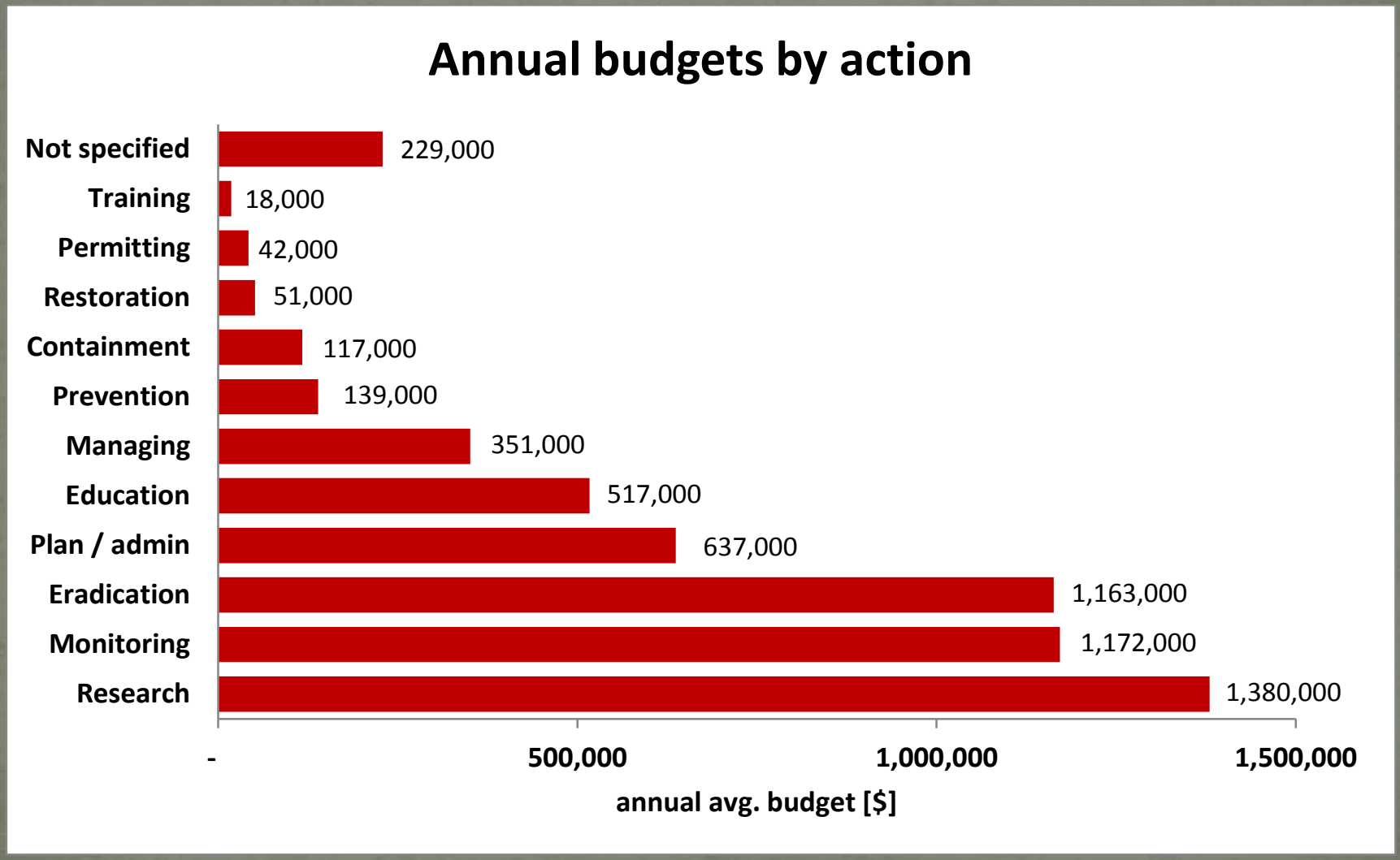
APPENDIX C

Ecosystems being targeted



APPENDIX C

What actions are taking place?



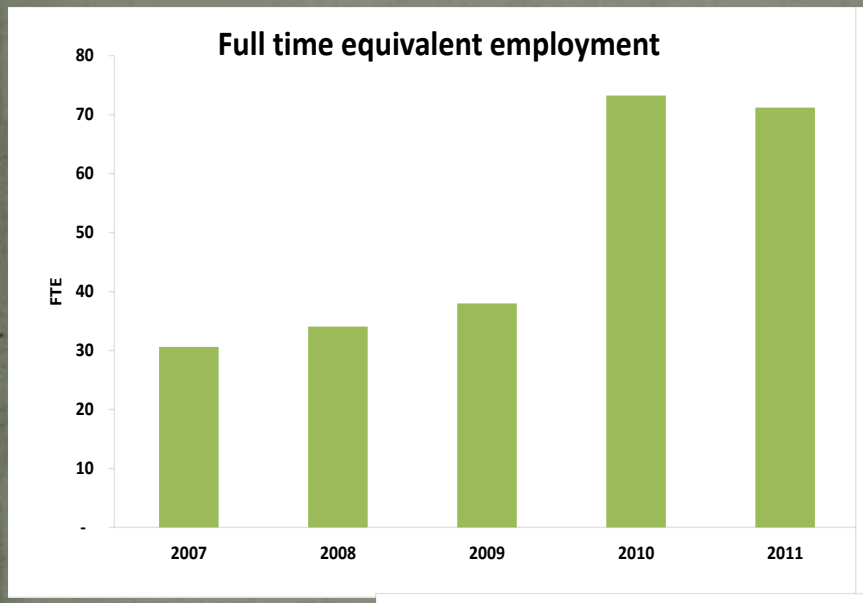
APPENDIX C

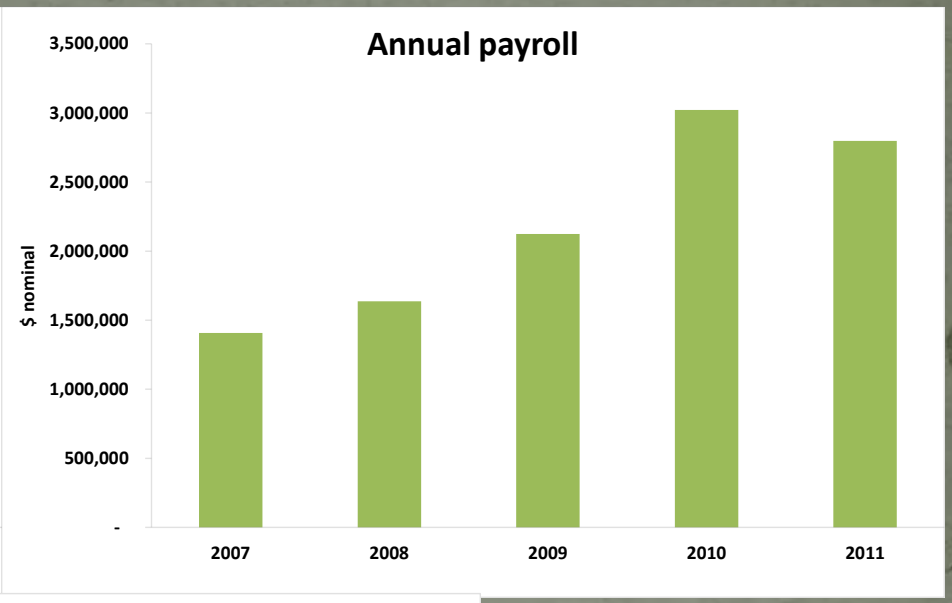
What are the budgets per organization?

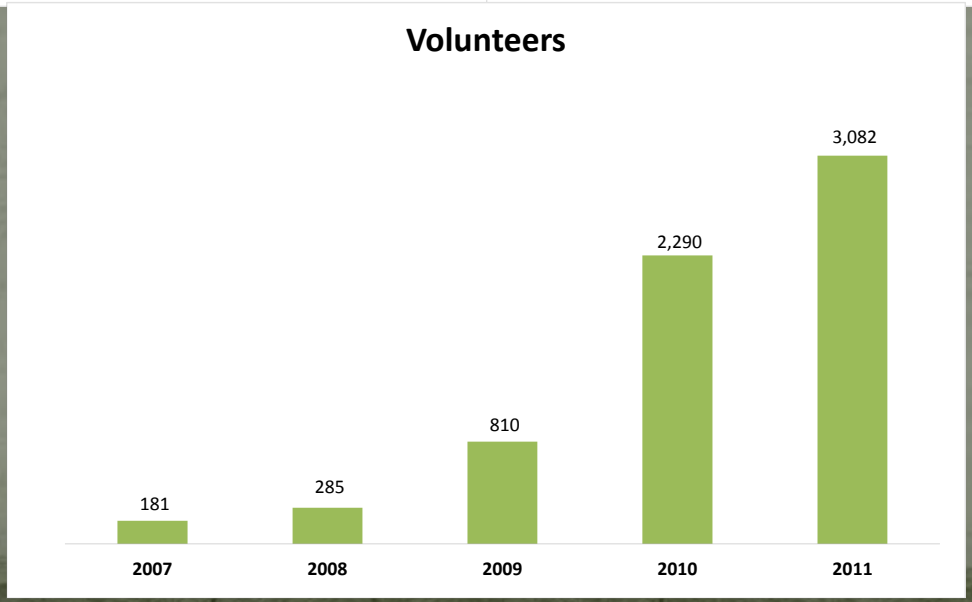
	5-yr mean
U.S. Fish and Wildlife Service	1,174,000
U.S. Department of Agriculture	1,016,000
The Nature Conservancy	429,000
Alaska Department of Fish and Game	419,000
National Park Service	348,000
Cook Inlet Aquaculture Association	341,000
Alaska Natural Heritage Program at UAA	301,000
Alaska Association of Conservation Districts	379,000
Alaska Cooperative Extension Service at UAF	166,000
Smithsonian Environmental Research Center	152,000
U.S. Forest Service	149,000
Alaska Department of Transportation	133,000

APPENDIX C

Employment, payroll, and volunteer efforts







Summary

- This project offers insight to historic spending on invasive species in AK between 2007-2011
- National trends and this study suggest there will be ongoing investments to address research, monitoring, eradication, and other actions related to invasive species in AK
- Alaska invasive species problem is in its infancy, but is not immune
- There is an influx of invasive species in Alaska due to increasing human population, development, and commerce
- There is increasing awareness and involvement by the public

Summary

- Total expenditures in AK ranged b/t $4.7-6.8M annually
- Primary funding sources and work efforts are currently through the federal agencies
- Bulk of funding for terrestrial plants and animals, but funds have increased slightly for marine and aquatic organisms
- Greatest actions taking place are research, monitoring, and eradication
- Funding has been highest in the SC and SW regions, although this has increased steadily for SE over the past 5 years
- Levels of increased employment, payroll, and volunteer effort

Conclusions

- Coordination of resources will become more critical in the future with increasing importance of the problem
- AK's early stage of the problem offers an opportunity for cost-effective solutions (i.e., EDRR and statewide coordination of stakeholders)
- Projection of potential future investment scenerios will help us to better understand economic costs for specific species

Many thanks!

- Funding provided by: PWSRCAC, USFWS, OASLC, Alaska Legislative Council, BLM
- All the agencies and organizations that contributed data!

APPENDIX D

Level	Agency/Organization: Division	Response		
Federal	Coastal and Ocean Resources	Reported by another agency (n = 1 of 1)	1	1
	Department of Interior: Bureau of Land Management	Responded (n = 3 of 3)	3	3
	Department of Interior: Bureau of Ocean and Energy Management	Responded (n = 1 of 1)	1	1
	Department of Interior: National Park Service	Responded (n = 1 of 1)	1	1
	Department of Interior: USFWS (Alaska Maritime, Arctic, Becharof, Innoko, Izembek, Kanuti, Kenai, Kodiak, Koyukuk-Nowitna, Tetlin, and Yukon Flats National Wildlife Refuges and Anchorage, Fairbanks, and Juneau Regional Offices	Responded (n = 17 of 17)	17	17
	Environmental Protection Agency	Responded (n = 1 of 1)	1	1
	National Oceanic and Atmospheric Administration	Responded (n = 1 of 1)	1	1
	Pacific Services	Reported by another agency (n = 1 of 1)	1	1
	Pacific States Marine Fisheries Commission	Reported by another agency (n = 1 of 1)	1	1
	Smithsonian Environmental Research Center	Responded (n = 1 of 1)	1	1
	United States Air Force	Responded (n = 1 of 1)	1	1
	United States Coast Guard	No Response (n = 0 of 1)	0	1
	United States Department of Agriculture: Agricultural Research Service	Responded (n = 1 of 1)	1	1
	United States Department of Agriculture: Animal and Plant Health Inspection Service	Responded (n = 1 of 1)	1	1
	United States Department of Agriculture: Natural Resources Conservation Service	No Response (n = 0 of 1)	0	1
	United States Department of Agriculture: United States Forest Service	Responded (n = 2 of 5)	2	5
	United States Geological Survey	No Response (n = 0 of 1)	0	1
State	Alaska Department of Fish and Game	Responded (n = 3 of 3)	3	3
	Alaska Department of Natural Resources	Responded (n = 1 of 1)	1	1
	Alaska Railroad Corporation	No Response (n = 0 of 1)	0	1
	Alaska State Legislature	Some Response (n = 0.5 of 1)	1	1
	Alaska Department of Transportation and Public Facilities	Some Response (n = 2 of 4)	2	4
	California State Lands Commission	Reported by another agency (n = 1 of 1)	1	1
	Kachemak Bay Estuarine Research Reserve	Responded (n = 1 of 1)	1	1
	State Pathology Lab	No Response (n = 0 of 1)	0	1
Tribal	Alaska Intertribal Council	No Response (n = 0 of 1)	0	1
	Bristol Bay Native Association	Responded (n = 1 of 1)	1	1
	Council of Athabascan Tribal Government	No Response (n = 0 of 1)	0	1
	Ekuk Village Council	No Response (n = 0 of 1)	0	1
	Metlakatla Indian Community	Responded (n = 1 of 1)	1	1
	Sitka Tribe of Alaska	Responded (n = 1 of 1)	1	1
Non-Profit	Alaska Assocation of Conservation Districts: Soil and Water Conservation Districts (Fairbanks, Homer, Kenai, Kodiak, Salcha-Delta, Seward, and Upper Susitna; No Response from Anchorage, Juneau, Mid Yukon-Kuskokwim, Palmer, and Wasilla)	Responded (n = 7 of 13)	7	13
	Alaska Parks Foundation	Responded (n = 1 of 1)	1	1
	Alaska SeaLife Center	Responded (n = 1 of 1)	1	1

APPENDIX D

Level	Agency/Organization: Division	Response		
Non-Profit	Citizens Against Noxious Weeds Invading the North	Reported by other agency (n = 1 of 1)	1	1
	Coast Alaska	Reported by other agency (n = 1 of 1)	1	1
	Coastal and Oceans Research Institute	Reported by other agency (n = 1 of 1)	1	1
	Cook Inlet Aquaculture Association	Responded (n = 1 of 1)	1	1
	Cook Inlet Regional Citizens Advisory Council	Reported by other agency (n = 1 of 1)	1	1
	Copper River Watershed Project	Reported by other agency (n = 1 of 1)	1	1
	Juneau Watershed Partership	No Response (n = 0 of 1)	0	1
	Kenai Watershed Forum	Responded (n = 1 of 1)	1	1
	Mat-Su Conservation Services	Responded (n = 1 of 1)	1	1
	Prince William Sound Regional Citizens Advisory Council	Responded (n = 1 of 1)	1	1
	Prince William Sound Science Center	Responded (n = 1 of 1)	1	1
	Resurrection Bay Conservation Alliance	Responded (n = 1 of 1)	1	1
	Sitka Sound Science Center	Responded (n = 1 of 1)	1	1
	Southeast Alaska Guidance Association	Reported by other agency (n = 1 of 1)	1	1
	Student Conservation Association	Reported by other agency (n = 1 of 1)	1	1
	The Nature Conservancy	Responded (n = 1 of 1)	1	1
	Trout Unlimited	Reported by other agency (n = 1 of 1)	1	1
Local	City and Borough of Juneau: CBJ Jensen-Olson Arboretum	Responded (n = 1 of 1)	1	1
	City of Sitka	Reported by other agency (n = 1 of 1)	1	1
	Municipality of Anchorage: Department of Public Works	Responded (n = 1 of 1)	1	1
	Yukon Flats School District	Reported by other agency (n = 1 of 1)	1	1
University	Alaska Pacific University	Responded (n = 2 of 2)	2	2
	Portland State University	Reported by other agency (n = 1 of 1)	1	1
	San Francisco State University: Romburg Tiburon Center for the Environment	Responded (n = 1 of 1)	1	1
	University of Alaska Anchorage: Alaska Natural Heritage Program, Institute of Social and Economic Research, and Turf Department	Responded (n = 3 of 3)	3	3
	University of Alaska Fairbanks: Alaska SeaGrant Marine Advisory Program and Cooperative Extension Service	Responded (n = 2 of 2)	2	2
	University of Alaska Southeast: Landscaping (No Response from Mchapman)	Responded (n = 1 of 2)	1	2
	University of Washington	Reported by other agency (n = 1 of 1)	1	1
Private	Alaska Botanical Garden	No Response (n = 0 of 1)	0	1
	Alaska Garden and Pet Supply	No Response (n = 0 of 1)	0	1
	Granite Construction Co.	No Response (n = 0 of 1)	0	1
	Ground Effects Landscaping	No Response (n = 0 of 1)	0	1
	Kachemak Bay Shelllfish Hatchery	No Response (n = 0 of 1)	0	1
	MISC Contractors	Reported by other agency (n = unknown)		
	PWS Oyster farm and shrimp trawling on Perry Island	No Response (n = 0 of 1)	0	1
			85	112

APPENDIX E

Alaska Invasive Species Economic Impact Study – Data Check List

Alaska SeaLife Center
windows to the sea

UAA Institute of Social and Economic Research
University of Alaska Anchorage

☐ **Your annual invasive species program's budget for the past five years (2007 – 2011):**

1. Budget (excel file or similar) for each year detailing:
2. Personnel:
    - Count of employees
    - Payroll
    - If available some measure of effort (labor hours, days, etc.)
3. Equipment:
    - Machinery, equipment rentals
4. Misc. supplies:
    - Herbicides, chemicals, office supplies, etc.
5. Volunteers:
    - Count of volunteers
    - Days annually where volunteers were present
    - If none applies, provide any other measure of volunteer effort
6. Amount of funding provided to other organizations:
    - Specify name of organization
    - Specify purpose of funding
7. List of invasive species you targeted that year

☐ **Additional information:**

- Specify "Actions" taken that year:
    1. Preparation of Permits or Environmental Impact Statements for proposed actions
    2. Intervention (specify as follows!)
        a. Prevention – stopping introductions
        b. Eradication – destroying/removing new invasion
        c. Containment – stopping new invasion from spreading
        d. Management – keeping established invasion from spreading
        e. Restoration – restoring ecosystem to initial state
    3. Monitoring
    4. Education / Outreach
    5. Research
    6. Other (specify!)
- Action budget amount
    - If unknown, try to approximate!
- Action species
    - Specify the invasive species

Please, continue next page!

APPENDIX E

Alaska Invasive Species Economic Impact Study – Data Check List

- Action location:
  - North, Southwest, Southeast, Southcentral, Interior
  - road system vs. remote
- Action area / action extend:
  - Total area treated (mile^2)
  - Stream length treated
  - Etc.
- Action success:
  - Provide some measure of success for the action in that year. This can be a qualitative or quantitative statement. For example, “eradicated, no re-growth for several years after treatment” or “density diminished by half”

Example for how you could provide the additional information:

Species name	**budget**	**Action (see list above)**	**Location**	**Area/extend of treatment**	**Measure of success**
Elodea	10% of annual budget	Eradication	Interior Fairbanks	5 square miles	Marginal success, Elodea came back one year after treatment
Green Alder Sawfly	$150,000	Monitoring	Southcentral	100 square miles	
…..	…	…			

Contact:

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Rebekka Federer

Alaska SeaLife Center

rebekkaf@alaskasealife.org

(907) 224-6377

Annual Invasive Species Program/Efforts Action

2007

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2008

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2009

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2010

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2011

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

* see also "annual budget" worksheet

APPENDIX F

Key for Spreadsheet

Specific action:
EIS Statements or Permitting
Intervention - Prevention (i.e., stopping introductions)
Intervention - Eradication (i.e., destroying/removing new invasions)
Intervention - Containment (i.e., stopping new invasion from spreading)
Intervention - Management (i.e., keeping established invasion from spreading
Intervention - Restoration (i.e., restoring ecosystem to initial state)
Monitoring
Education/Outreach
Research
Other (please specify!)

Action budget:
if unknown, try to approximate

Action species:
Specify the invasive species

Action location:
North, Southwest, Southeast, Southcentral, Interior
road system vs. remote

Action area/extent (this will vary by action, but below are some examples of ways that you could report for each action:
Total area treated (miles squared)
Stream length treated
monitoring traps/plates used
people reached for Education/Outreach

Action success:
Provide some measure of success for the action. This can be a qualitative or quantitative statement (e.g.,
"eradicated, no re-growth for several years after treatment" or " density dimished by half")

APPENDIX F1

Annual Invasive Species Program/Efforts Budget

		YEARS				
Category	**Description**	**2007**	**2008**	**2009**	**2010**	**2011**
Personnel	Count of Employees					
	Payroll					
	Measure of effort if available (labor hours, days, etc.)					
Equipment	Machinery, equipment rentals					
Misc Supplies	Herbicides, chemicals, office supplies, etc.					
Volunteers	Count of volunteers					
	Days annually where volunteers were present					
	If none applies, provide any other measure of volunteer effort					
Amount of funding provided to other organizations	Specify name of organization					
	Specify purpose of funding					
Targeted invasive species	List of invasive species you targeted each year					

* see also "annual actions" worksheet

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Annual Invasive Species Program/Efforts Action

2007

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2008

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2009

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2010

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

2011

Species Name	Budget	Action	Location	Area/Extent	Measure of Success

* see also "annual budget" worksheet

APPENDIX F2

Key for Spreadsheet

Specific action:
EIS Statements or Permitting
Intervention - Prevention (i.e., stopping introductions)
Intervention - Eradication (i.e., destroying/removing new invasions)
Intervention - Containment (i.e., stopping new invasion from spreading)
Intervention - Management (i.e., keeping established invasion from spreading
Intervention - Restoration (i.e., restoring ecosystem to initial state)
Monitoring
Education/Outreach
Research
Other (please specify!)

Action budget:
if unknown, try to approximate

Action species:
Specify the invasive species

Action location:
North, Southwest, Southeast, Southcentral, Interior
road system vs. remote

Action area/extent (this will vary by action, but below are some examples of ways that you could report for each action:
Total area treated (miles squared)
Stream length treated
monitoring traps/plates used
people reached for Education/Outreach

Action success:
Provide some measure of success for the action. This can be a qualitative or quantitative statement (e.g.,
"eradicated, no re-growth for several years after treatment" or " density dimished by half")

APPENDIX G

Economic Impact Study of Invasive Species in Alaska

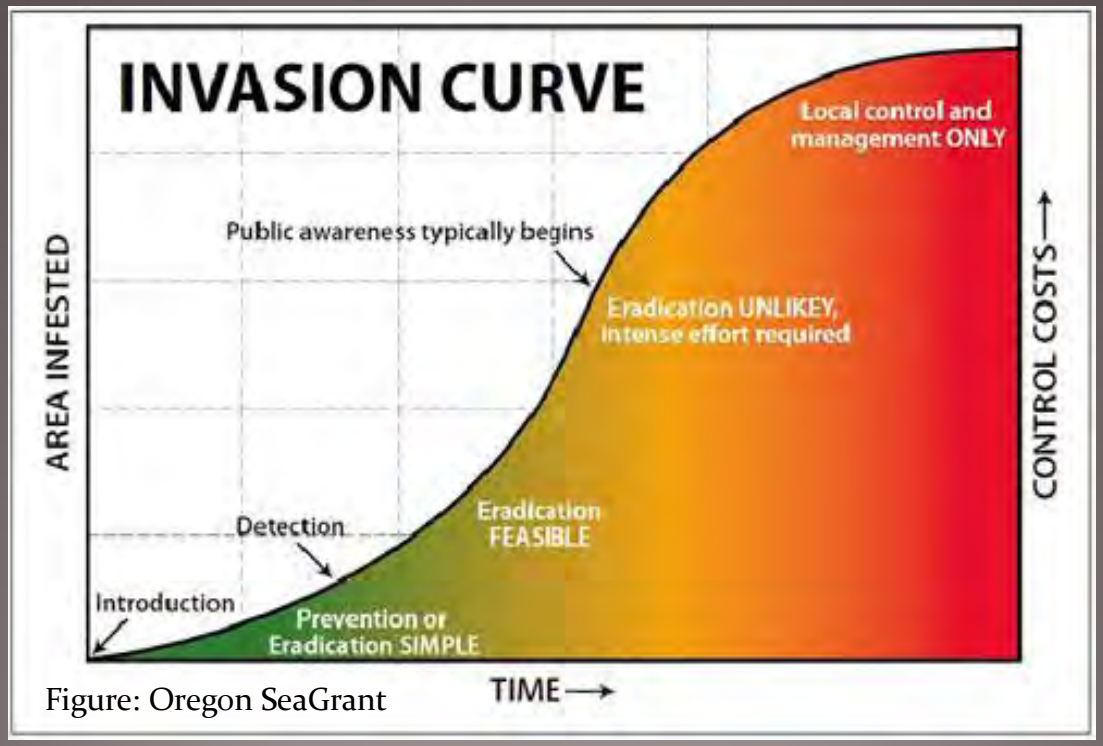


Figure: Oregon SeaGrant

Rebekka Federer, Marine Invasive Species Program Manager

Howard Ferren, Director of Conservation

Kira Hansen, Conservation AmeriCorps Member

Tobias Schwoerer and Steve Colt, Economists

Invasive Species-What's at stake?

- Non-native species 'whose introduction does or is likely to cause economic or environmental harm, or harm to human health' *(Federal Register 1999)*
- ~Eco. and environ. costs total more than $137B/year for losses, damages, and control in US *(Pimentel et al. 1999)*
- Impacts to human health; biodiversity; jobs in fishing, mariculture, recreation, and tourism; food resources; property values; and more!
- A few current examples…….tunicates, waterweeds, reed canarygrass, pike, and rats, oh my!!

Didemnum vexillum
marine vomit

- Few known predators, smothers substrate and organisms, impacts mariculture, alters ecosystem integrity, has impacts on eelgrass and seagrass communities important for nursery habitat

Elodea nuttallii
western waterweed

- Degraded fish habitat, difficulty with boat travel, alter freshwater habitat

Phalaris arundinacea
Reed canarygrass


Photo: USFS

- Reduces biodiversity, alters hydrology, and limits tree regeneration

Esox lucius
Northern Pike

- Native in some parts of Alaska but introduced in others
- Piscivorous fish, causes large-scale changes in fish communities

Rattus norvegicus
Norway rat

- Decimated seabird populations by eating adults and eggs in island and coastal habitat

How the project came about?

- MIS Workshop held by AISWG (March 2010)
  - MIS Reps. from AK, HI, WA, CA, BC, D.C. attended
  - Six key priorities and 11 near-term actions developed:
    - *Research and Development – Economic Impact Study*
    - Presentations and Workshop Report: http://www.alaskasealife.org/New/research/mis_workshop.php

Need for Economic Study in AK

- Invasive species costs for Alaska are not known!
- Discipline and methods of economics provides tools needed to inform managers/policymakers about costs of invasive species and cost-benefit of different strategies
- Provide leverage to establish an Organizing Body
  - *Workshop Priority and Near-Term Action Item: Management and Coordination – Invasive Species Council*
- Need greater support from the AK Legislature to provide resources and direct managers to be more responsive
  - Bills for invasive species introduced but did not pass

Project Phases

- Phase 1: Literature Review (completed)
- Phase 2: Data collection (completed)
- Phase 3: Data Analysis (underway)
- Phase 4: Report (underway, Final = summer 2012)

Phase 1: Literature review

- Collected literature on any available economic impact studies
- Collected papers useful for modeling specific species: (e.g., spotted knapweed, creeping thistle, *D.vex*, *Elodea*, EGC, knotweed *spp*., WSC, RCG, parasites
  - Year introduced, cost/area, % dispersal rate/year, carrying capacity area
- Almost 175 articles thus far!

Phase 2: Data collection

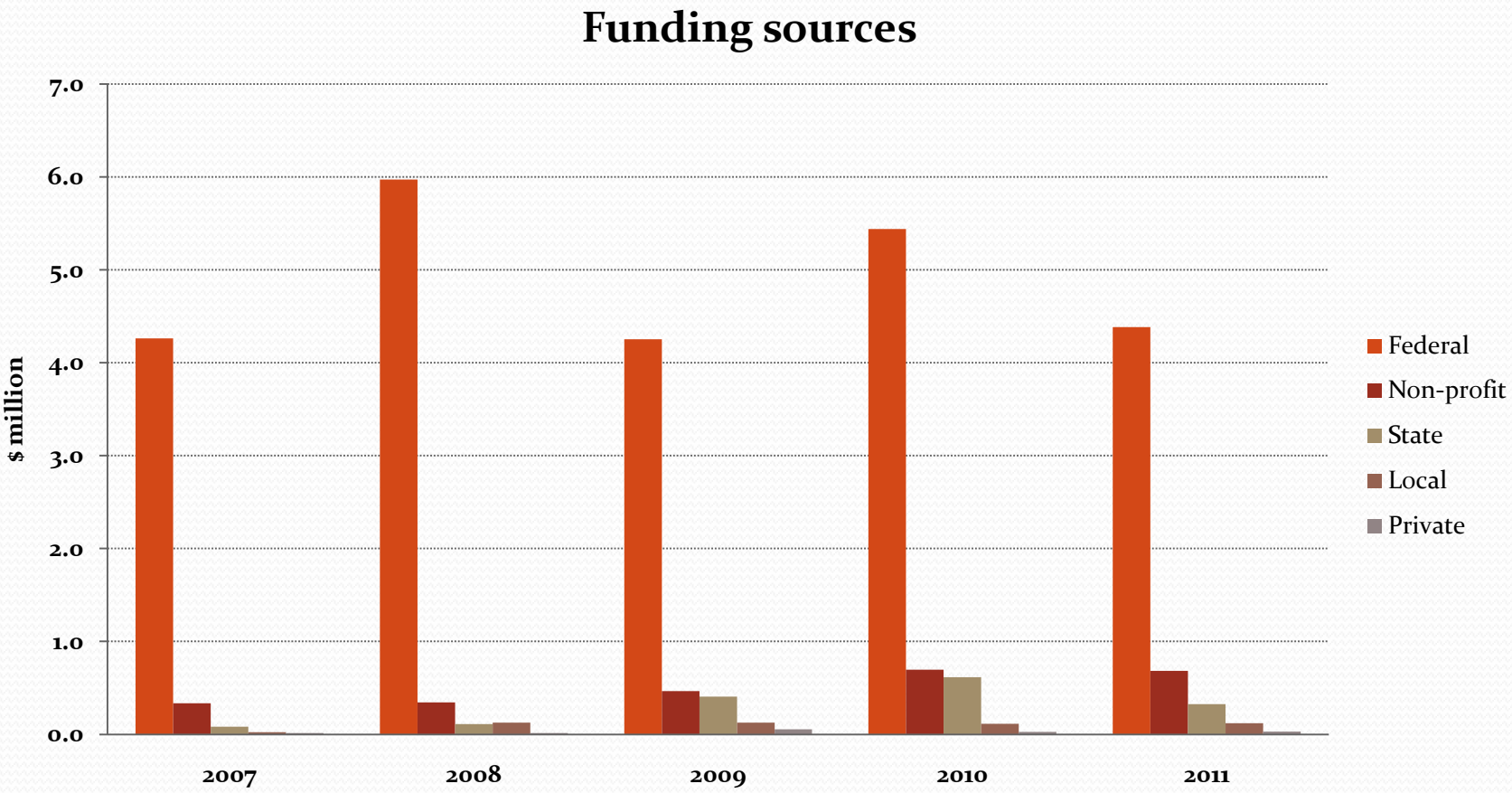
- Contact all agencies and organizations that may have contributed to invasive species work in AK
- Aimed to collect 5 years of data (2007-2011)
- Collected data from November 2011-March 2012
- Datasheet included monetary information for personnel, equipment, and supplies; volunteer info; funding dispersal; and info for species, action, location, area/extent, measure of success
- Data gathered from $$ source and receiver of $$
- Info from 84 individuals from 48 agencies/organizations

Phase 3: Data Analysis

- Establish baseline data for costs of invasive species, analyze changes in investment levels over time, how money is used, and how money is dispersed
- Project potential future investment scenerios
- Additional economic modeling costs for specific species:
  - ISER evaluating available models through USGS (e.g., RCG*, WSC*, Canada thistle, knotweed spp., spotted knapweed)
  - No available models for other species, but ISER can develop simplistic models (e.g., marine vomit, western waterweed, Northern pike, EGC)

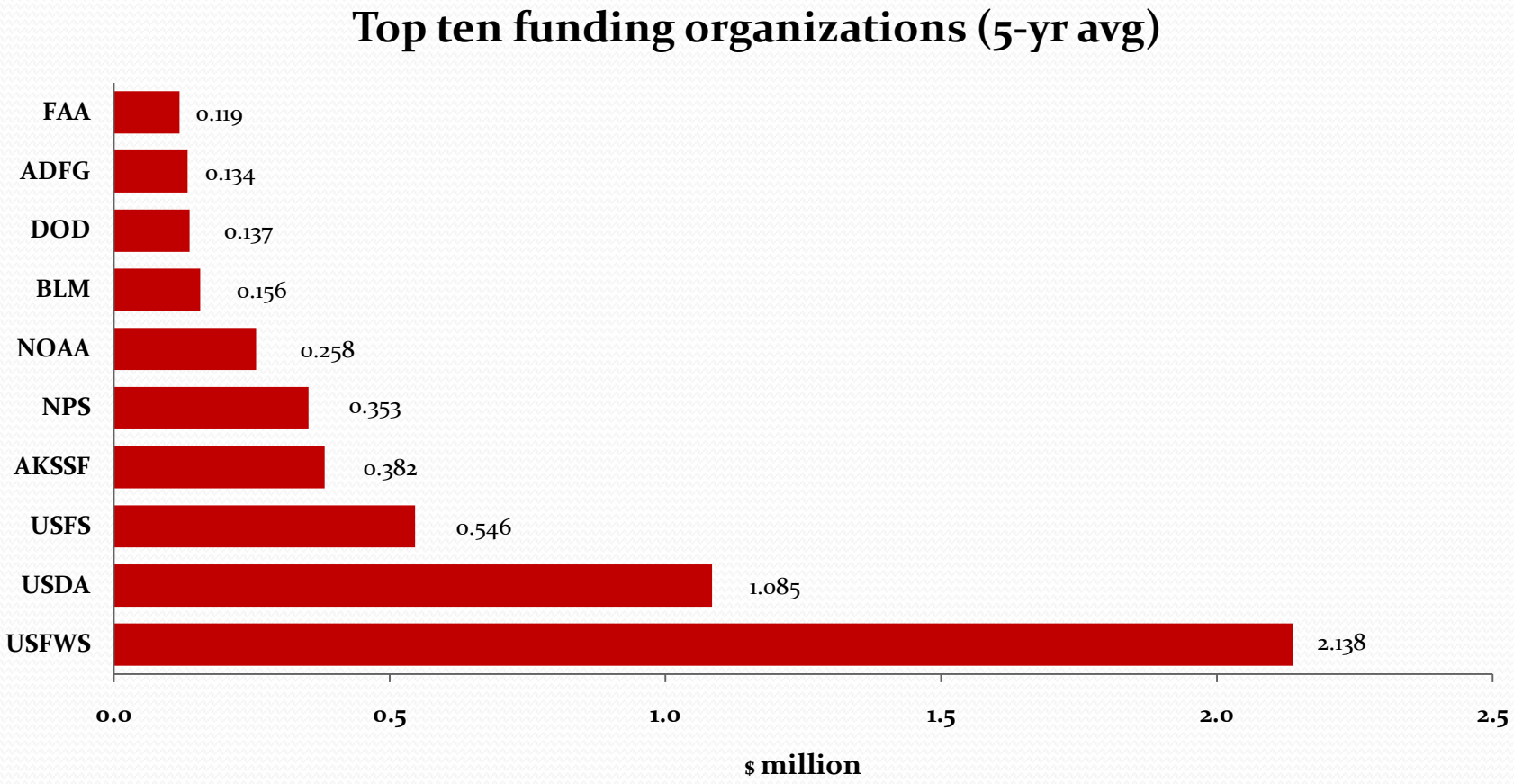
Phase 3: Data Analysis

Preliminary results



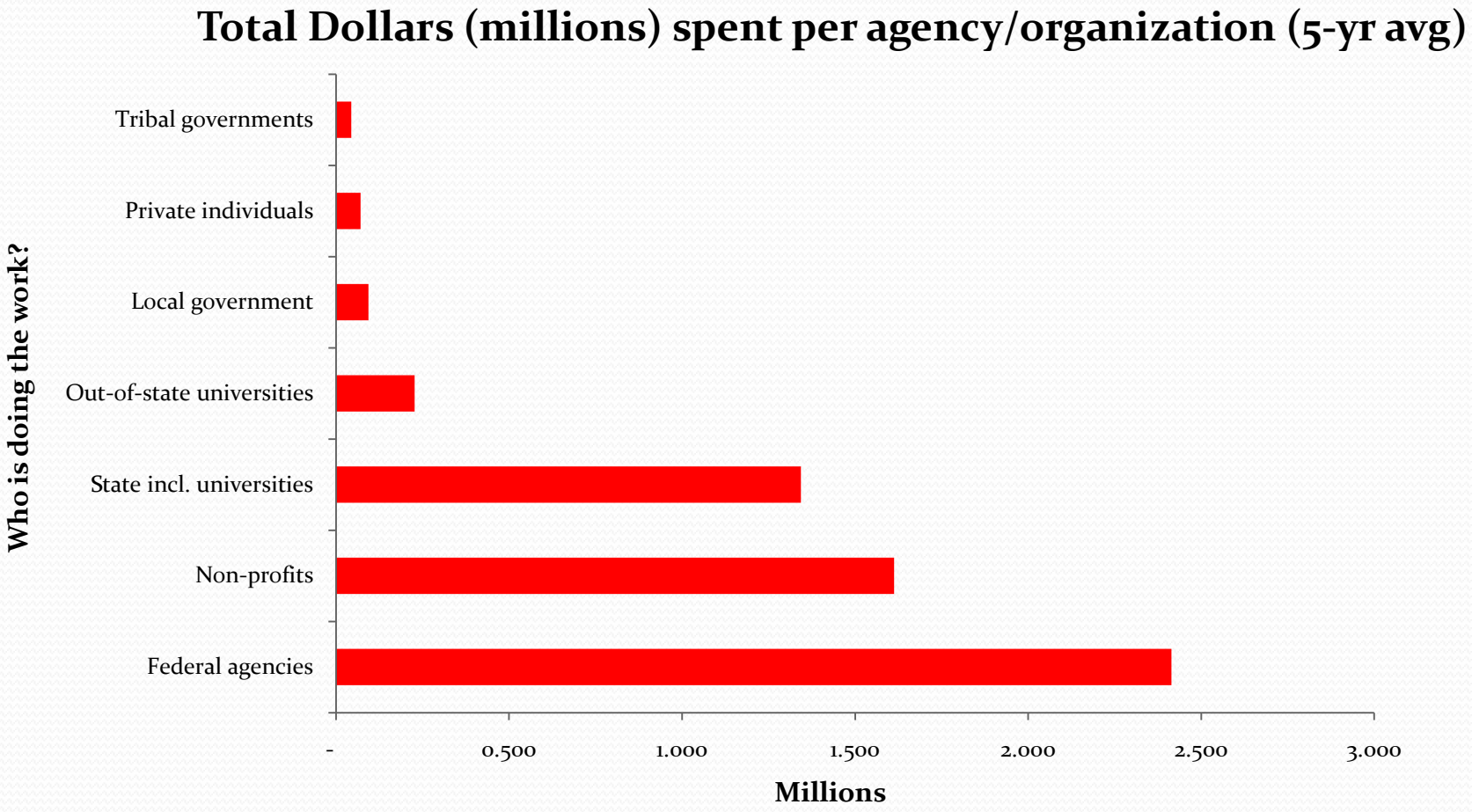
Phase 3: Data Analysis

Preliminary results



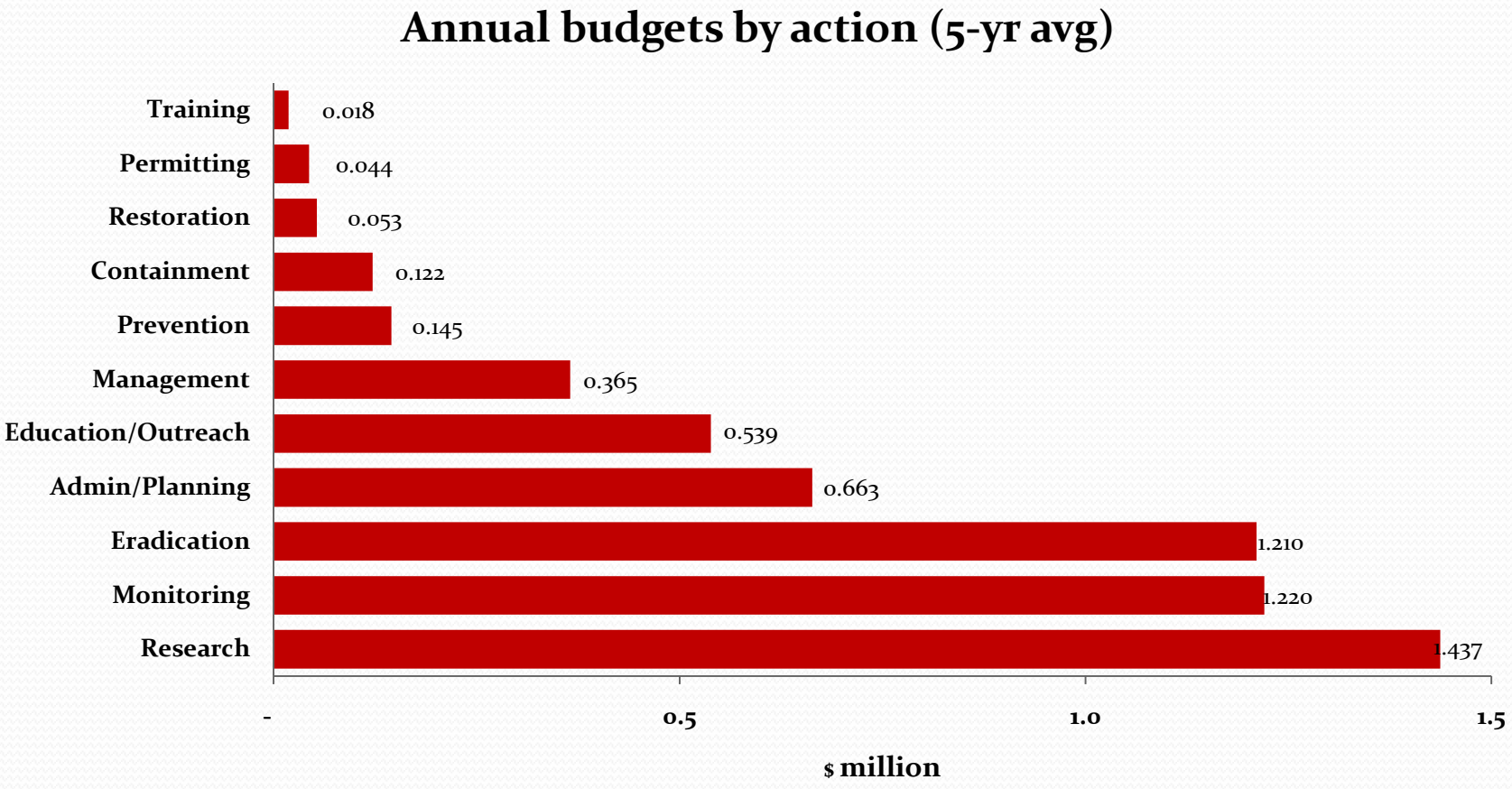
Phase 3: Data Analysis

Preliminary results



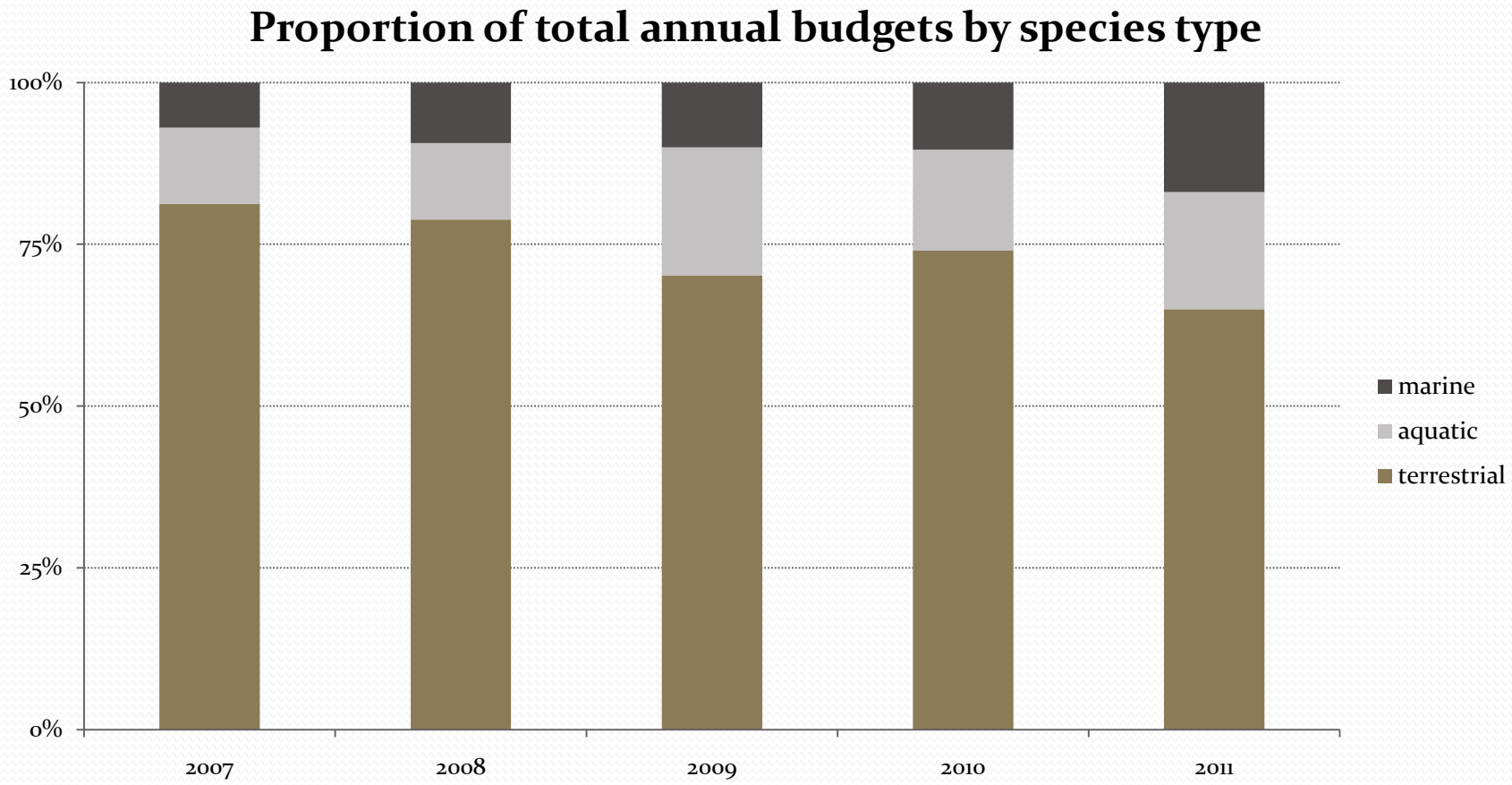
Phase 3: Data Analysis

Preliminary results



Phase 3: Data Analysis

Preliminary results



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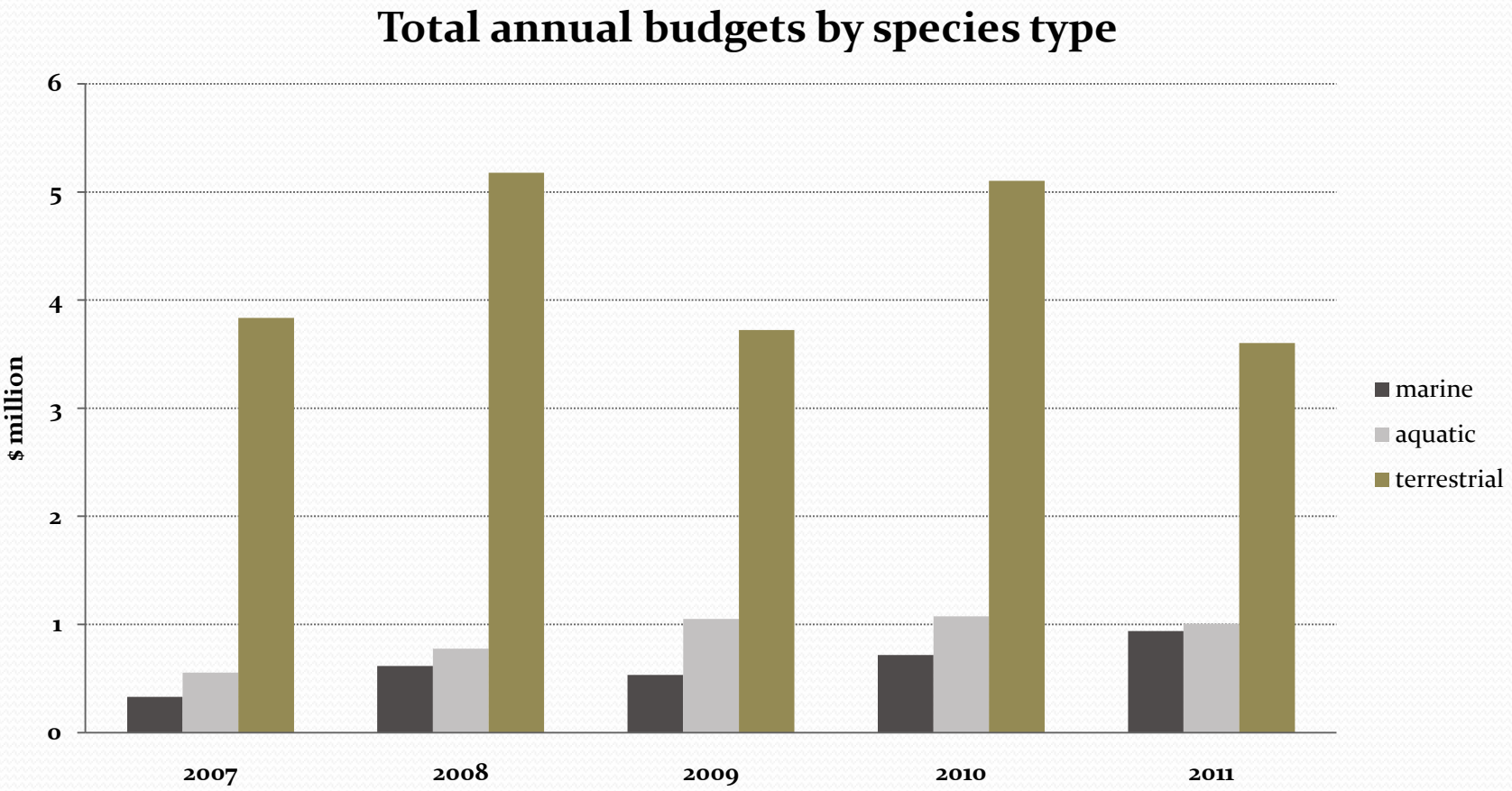

"Until prevention speaks the language of economics as well as ecology, it will consistently take a back seat to transportation and trade."

—Jason Van Driesche and Roy Van Driesch 2001

"In the long term, economic sustainability depends on ecological sustainability."

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Many thanks!

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- Stay tuned for the rest of the story……expected date of Final Report at the end of summer 2012.

APPENDIX G

Economic Impact Study of Invasive Species in Alaska

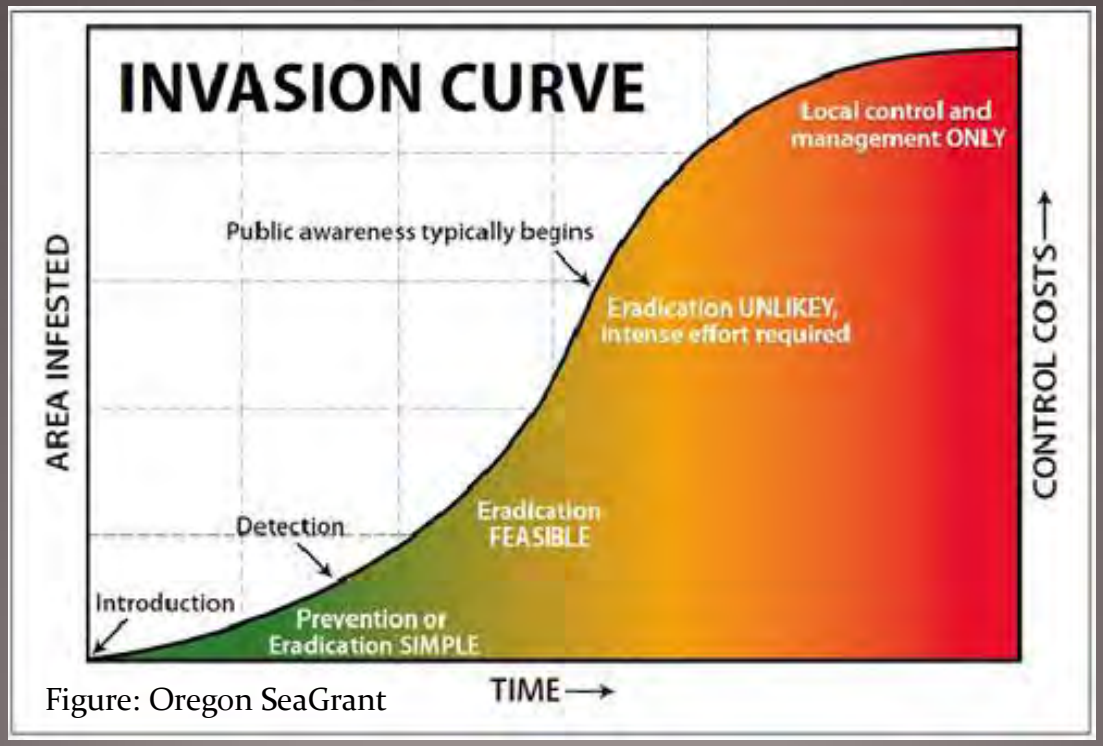


Figure: Oregon SeaGrant

Rebekka Federer, Marine Invasive Species Program Manager

Howard Ferren, Director of Conservation

Kira Hansen, Conservation AmeriCorps Member

Tobias Schwoerer and Steve Colt, Economists

Invasive Species-What's at stake?

- Non-native species 'whose introduction does or is likely to cause economic or environmental harm, or harm to human health' *(Federal Register 1999)*
- ~Eco. and environ. costs total more than $137B/year for losses, damages, and control in US *(Pimentel et al. 1999)*
- Impacts to human health; biodiversity; jobs in fishing, mariculture, recreation, and tourism; food resources; property values; and more!
- A few current examples…….tunicates, waterweeds, reed canarygrass, pike, and rats, oh my!!

Didemnum vexillum
marine vomit

- Few known predators, smothers substrate and organisms, impacts mariculture, alters ecosystem integrity, has impacts on eelgrass and seagrass communities important for nursery habitat

Elodea nuttallii
western waterweed

- Degraded fish habitat, difficulty with boat travel, alter freshwater habitat

Phalaris arundinacea
Reed canarygrass


Photo: USFS

- Reduces biodiversity, alters hydrology, and limits tree regeneration

Esox lucius
Northern Pike

- Native in some parts of Alaska but introduced in others
- Piscivorous fish, causes large-scale changes in fish communities

Rattus norvegicus
Norway rat

- Decimated seabird populations by eating adults and eggs in island and coastal habitat

How the project came about?

- MIS Workshop held by AISWG (March 2010)
  - MIS Reps. from AK, HI, WA, CA, BC, D.C. attended
  - Six key priorities and 11 near-term actions developed:
    - *Research and Development – Economic Impact Study*
    - Presentations and Workshop Report: http://www.alaskasealife.org/New/research/mis_workshop.php

Need for Economic Study in AK

- Invasive species costs for Alaska are not known!
- Discipline and methods of economics provides tools needed to inform managers/policymakers about costs of invasive species and cost-benefit of different strategies
- Provide leverage to establish an Organizing Body
  - *Workshop Priority and Near-Term Action Item: Management and Coordination – Invasive Species Council*
- Need greater support from the AK Legislature to provide resources and direct managers to be more responsive
  - Bills for invasive species introduced but did not pass

Project Phases

- Phase 1: Literature Review (completed)
- Phase 2: Data collection (completed)
- Phase 3: Data Analysis (underway)
- Phase 4: Report (underway, Final = summer 2012)

Phase 1: Literature review

- Collected literature on any available economic impact studies
- Collected papers useful for modeling specific species: (e.g., spotted knapweed, creeping thistle, *D.vex*, *Elodea*, EGC, knotweed *spp*., WSC, RCG, parasites
  - Year introduced, cost/area, % dispersal rate/year, carrying capacity area
- Almost 175 articles thus far!

Phase 2: Data collection

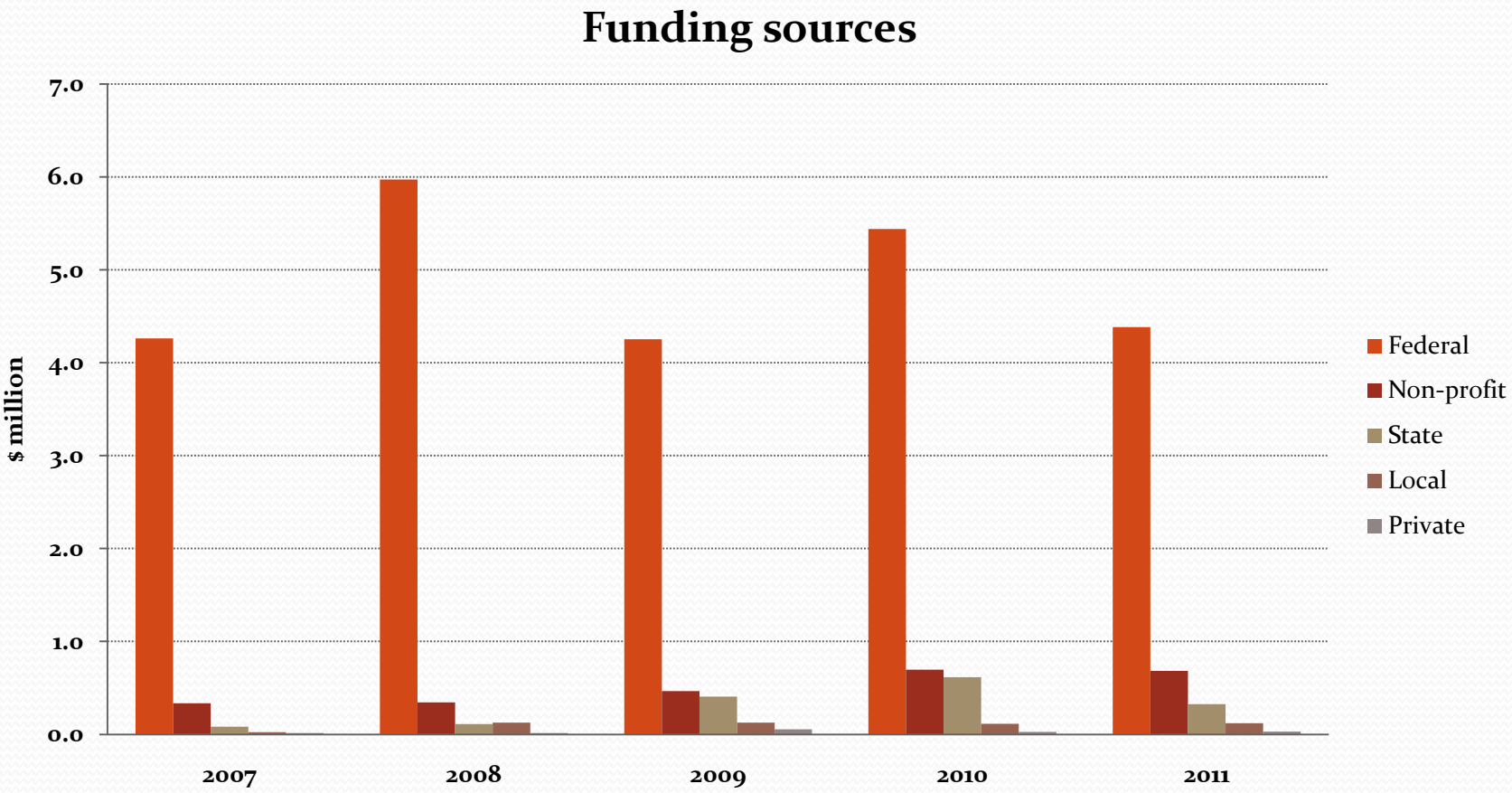
- Contact all agencies and organizations that may have contributed to invasive species work in AK
- Aimed to collect 5 years of data (2007-2011)
- Collected data from November 2011-March 2012
- Datasheet included monetary information for personnel, equipment, and supplies; volunteer info; funding dispersal; and info for species, action, location, area/extent, measure of success
- Data gathered from $$ source and receiver of $$
- Info from 84 individuals from 48 agencies/organizations

Phase 3: Data Analysis

- Establish baseline data for costs of invasive species, analyze changes in investment levels over time, how money is used, and how money is dispersed
- Project potential future investment scenerios
- Additional economic modeling costs for specific species:
  - ISER evaluating available models through USGS (e.g., RCG*, WSC*, Canada thistle, knotweed spp., spotted knapweed)
  - No available models for other species, but ISER can develop simplistic models (e.g., marine vomit, western waterweed, Northern pike, EGC)

Phase 3: Data Analysis

Preliminary results



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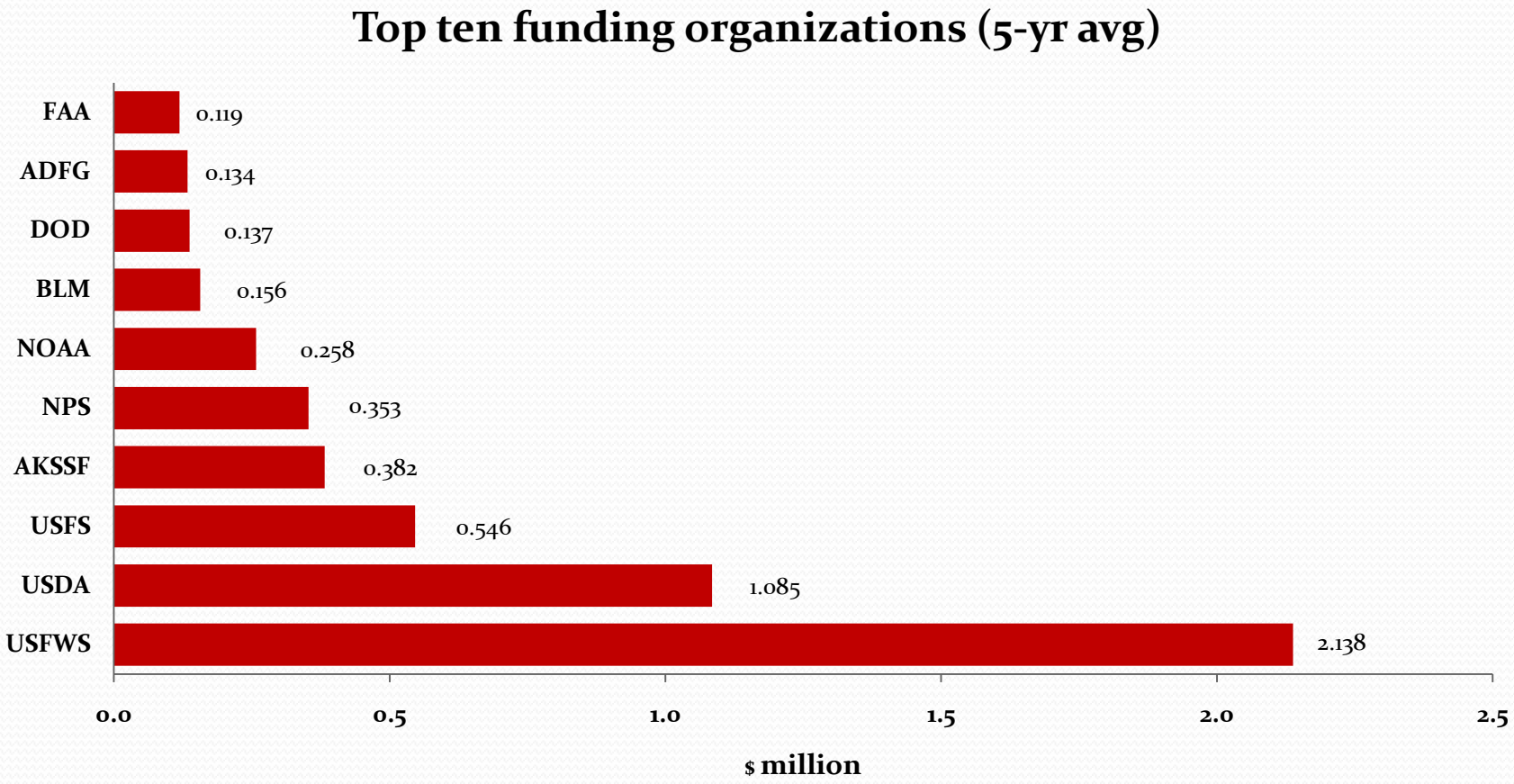

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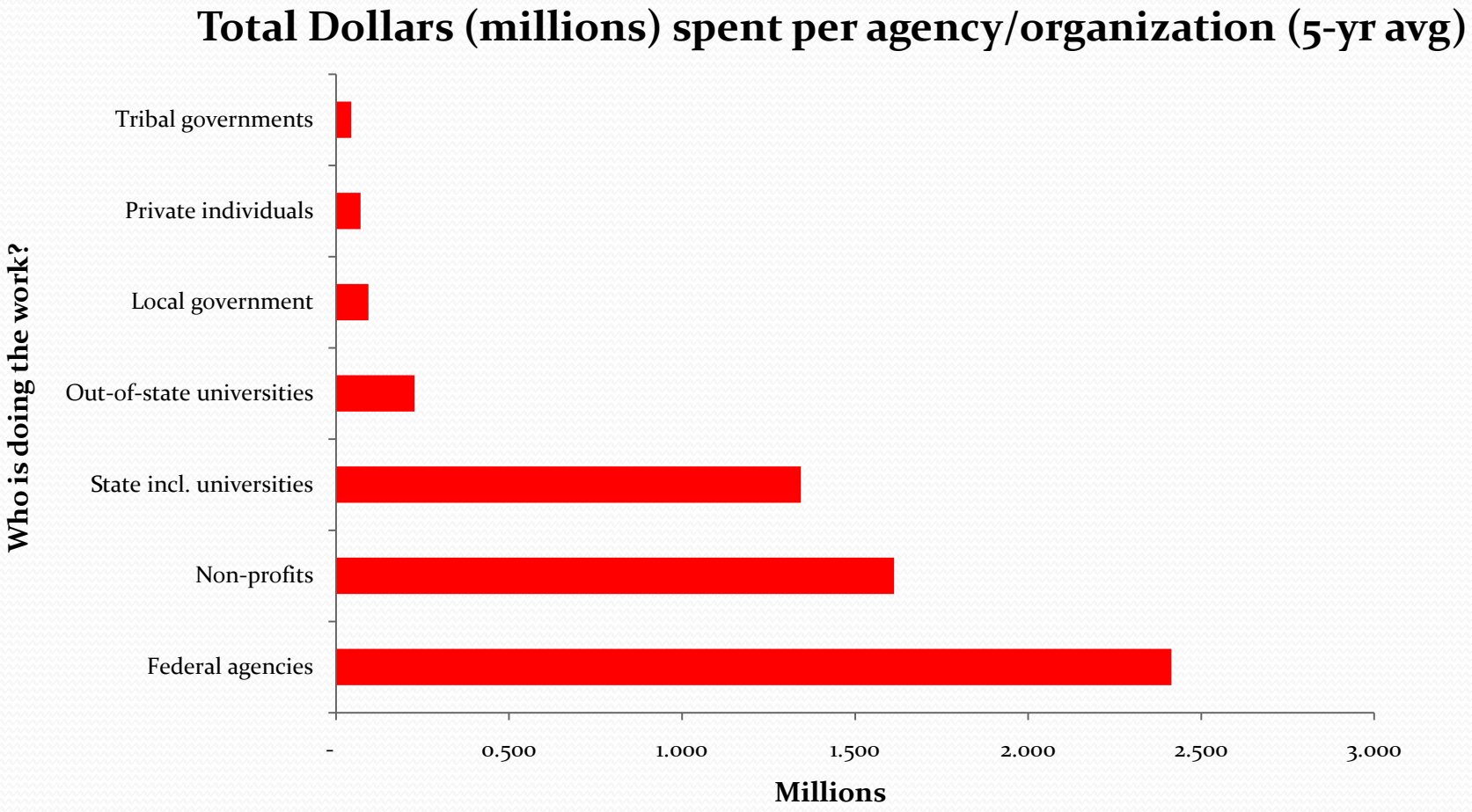

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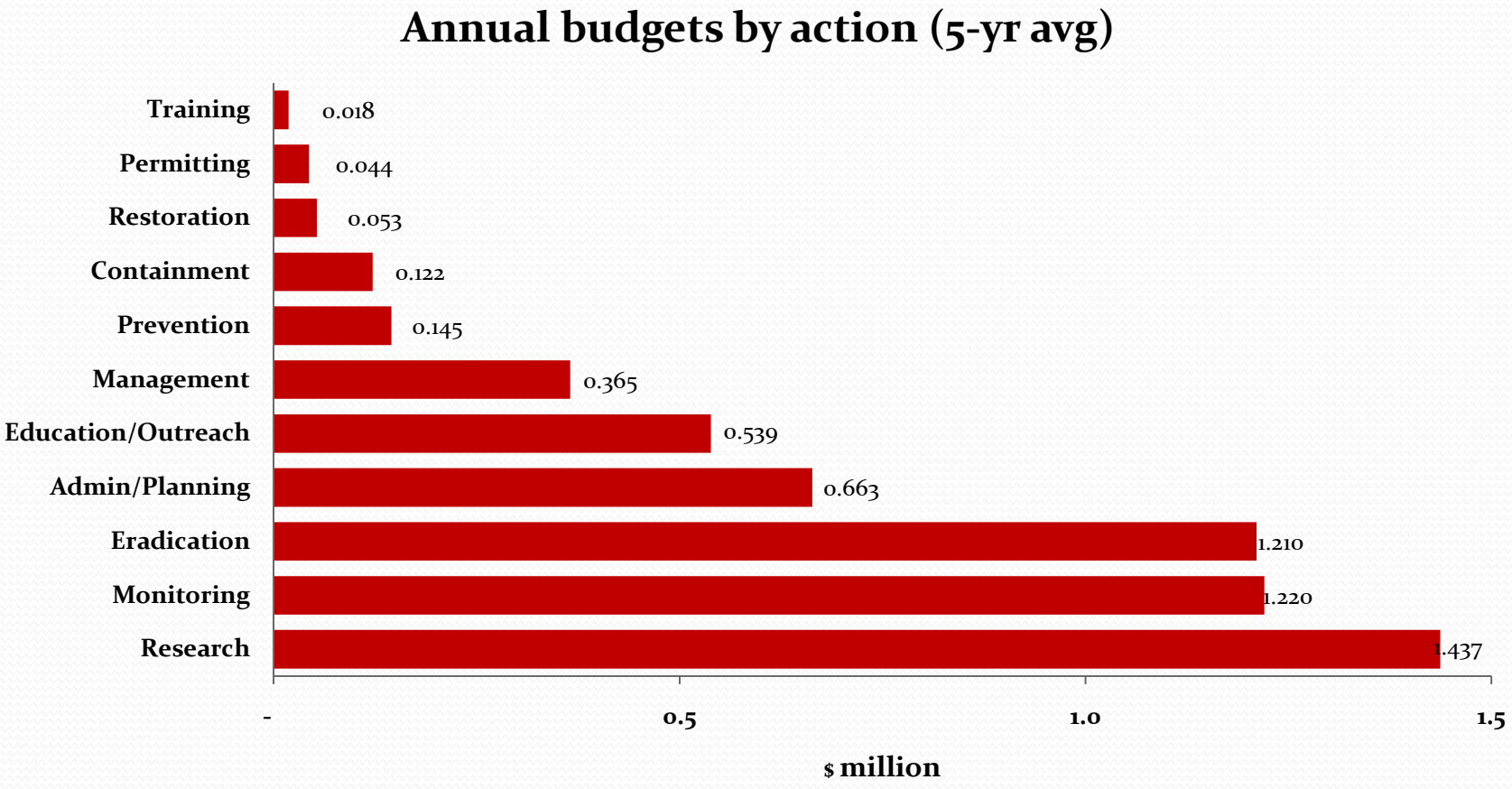

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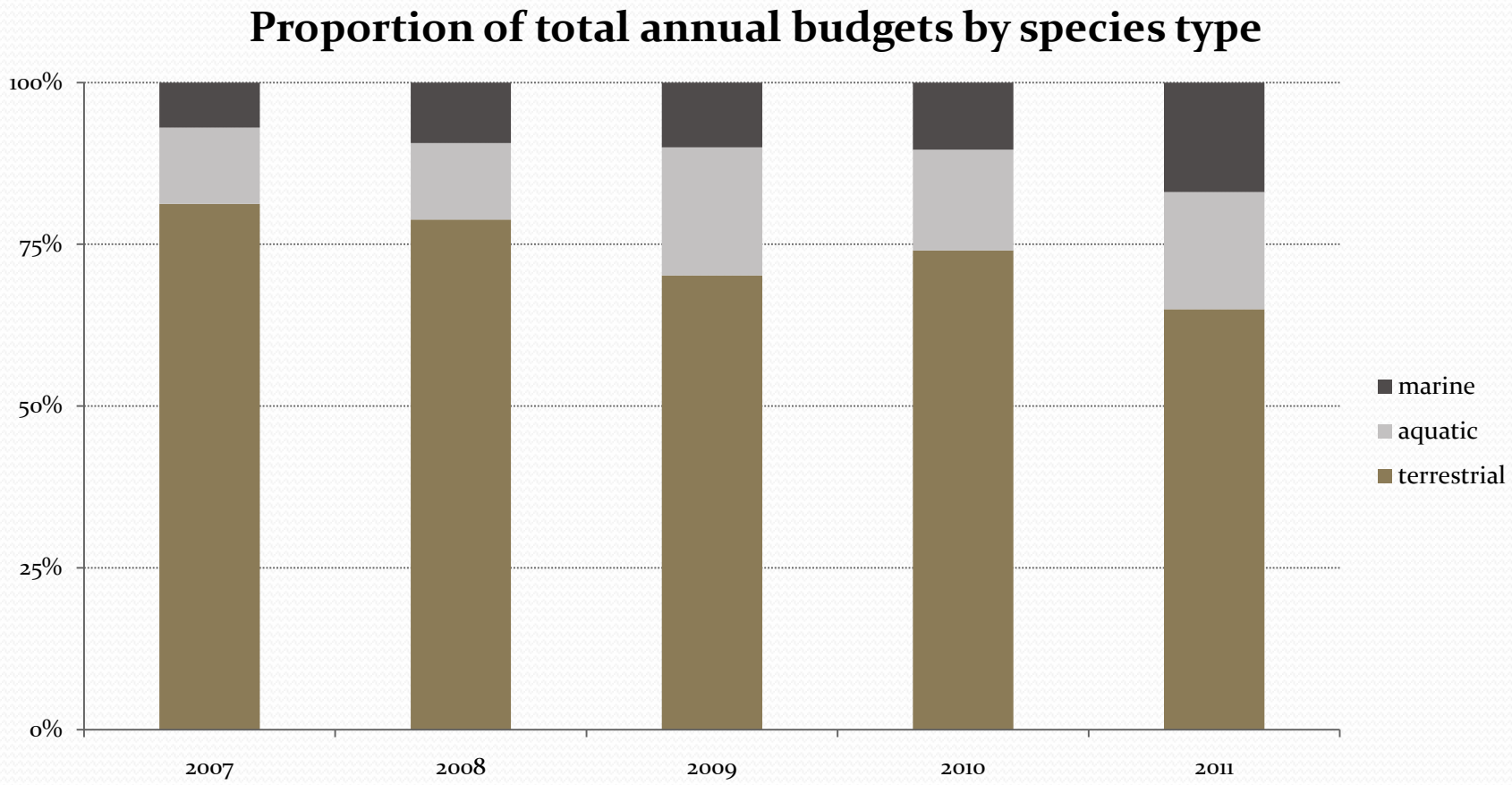

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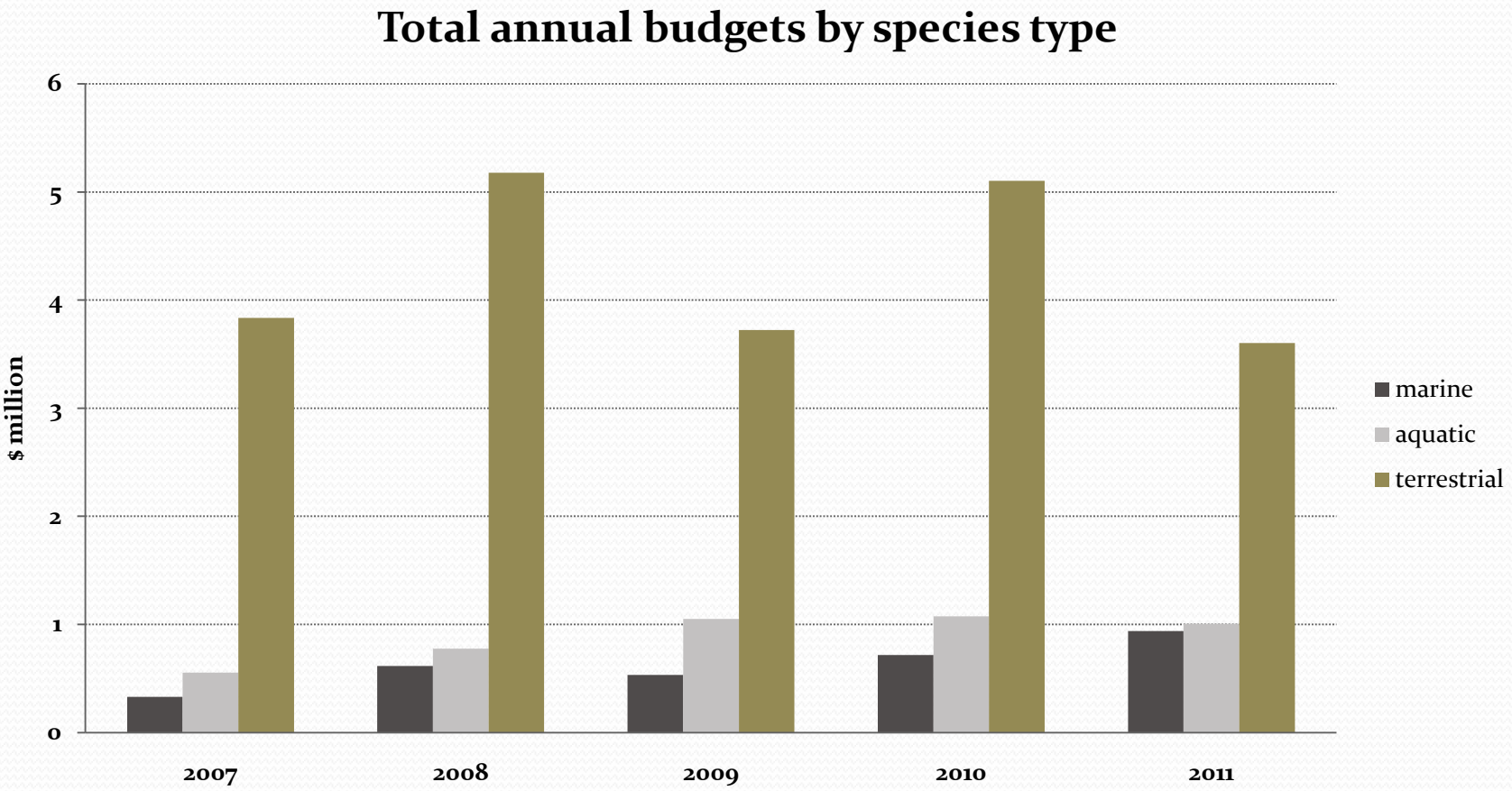

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- Stay tuned for the rest of the story……expected date of Final Report at the end of summer 2012.

APPENDIX H

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
Alaska Marine Invasive Species Workshop Summary and Recommendations	2010	Alaska Invaisve Species Working Group	Document	http://www.alaskasealife.org/New/research/mis_documents/MIS%20Workshop%20Proceedings.pdf
"Economic evaluation of biological invasions- a survey"	2004	Born, W., Rauschmayer F., Bräuer, I.	Document	http://econstor.eu/bitstream/10419/45201/1/396466451.pdf
"Novel contaminants and pathogens in coastal waters"	2004	CIESM	Document	http://www.ciesm.org/online/monographs/NeuchatelExecSum.pdf
"Invasive Alien Species A Threat To Biodiversity"	2009	Convention on Biological Diversity	Document	http://www.cbd.int/doc/bioday/2009/idb-2009-booklet-en.pdf
"The Economics of Invasive Species"	2009	Cusack, C., M. Harte, S. Chan	Document	http://www.oregon.gov/OISC/docs/pdf/economics_invasive.pdf?ga=t
"Early Detection and Rapid Response Plan for the European Green Crab, *Carinus maenas,* in Alaska"	2009	Davidson, T., A. Larson, C. de rivera	Document	Partial print. ASLC Ntwk: T:\Stewardship\Invasive Marine Species\Literature, fact sheets, posters etc\D folder\Davidson folder
"Hull fouling is a risk factor for intercontinental species exchange in aquatic ecosystems"	2007	Drake, J.M., D.M. Lodge	Aquatic Invasions (2007) Volume 2, Issue 2: 121-131 DOI 10.3391/ai.2007.2.2.7	www.vliz.be/imisdocs/publications/155934.pdf
"Potential microbial bioinvasions: evaluating options for ballast water management"	2007	Drake, L.A., M.A. Doblin, F.C. Dobbs	Marine Pollution Bulletin 55 (2007) 333–341 doi:10.1016/j.marpolbul.2006.11.007	http://www.clr.pdx.edu/mbic/papers/microbialbioinvasions.pdf
"Global redistribution of bacterio-plankton and virioplankton communities"	2001	Drake, LA.	Biological Invasions Volume 3, Number 2 (2001), 193-199, DOI: 10.1023/A:1014561102724	http://www.springerlink.com/content/j2tbpalxuh6486hj/fulltext.pdf
"A Toolkit for the Economic Analysis of invasive Speices"	2008	Emerton, L., G. Howard. GiSP	Document	http://www.gisp.org/publications/toolkit/Economictoolkit.pdf
Economic Issues of Invasive Pests and Diseases and Food Safety	2002	Evans, Edward A., Spreen, Thomas H., Knapp, J.L.	Document	http://ideas.repec.org/b/ags/uflomo/15696.html

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
"Pathogenic Human Viruses in Coastal Waters"	2003	Griffin, D.W., K. Donaldson, J. Paul, J. Rose	Clinical Microbiology Reviews,16(1): 129–143 DOI: 10.1128/CMR.16.1.129–143.2003	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC145303/pdf/0008.pdf
"Transport of toxic dinoflagellates via ships ballast water: bioeconomic risk assessment and efficacy of possible ballast water management strategies"	1998	Hallegraff G.M.	Marine Ecology Progress Series 168: 297-309	http://www.int-res.com/articles/meps/168/m168p297.pdf
"Non-native species impacts on native salmonids in the Columbia River Basin"	2008	Independent Scientific Advisory Board	Document	ISAB 2008-4. Northwest Power and Conservation Council
"Using contingent valuation to estimate the value of forest ecosystem protection"	2003	Kramer, R. A., T. P. Holms and M. Haefele	Document	fds.duke.edu/db/attachment/405
"Invasive Species (human-induced)"	2010	Lassuy, D., P. Lewis	Arctic Biodiversity Trends 7: 45-48	http://abt.arcticportal.org/images/stories/report/pdf/Indicator_07_Invasives_species__human_induced.pdf
"An Ounce of Prevention or a Pound of Cure: Bioeconomic Risk Analysis of Invasive Species"	2002	Leung, B. D.M. Lodge, D. Finnoff, J.F. Shogren, M.A. Lewis and G. Lamberti	Proc. R. Soc. Lond. B (2002) 269, 2407–2413 DOI 10.1098/rspb.2002.2179	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1691180/pdf/12495482.pdf
"The Ecnomic Impacts of Aquatic Invasive Speicies: A Review of the Literature"	2006	Lovell, S., S. Stone Mack, R., D.	Agricultural and Resource Economics Review 35/1 (April 2006) 195–208	http://ageconsearch.umn.edu/bitstream/10175/1/35010195.pdf
"Biotic Invasions: Causes, Epidemiology, Global Consequences and Control"	2000	Simberloff, M. Lonsdale, H. Evans, M. Clout, F. Bazzaz	Issues in Ecology 5: 1-20	http://www.epa.gov/owow/watershed/wacademy/acad2000/pdf/issue5.pdf
"Non-Native and Invasive Animals of Alaska: A Comprehensive List and Select Species Status Reports"	2008	McClory, J. and T. Gothard	Document	http://www.adfg.alaska.gov/static/species/nonnative/invasive/pdfs/invasivespp_report.pdf

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
"Invasive Species and Delaying the Inevitable: Valuation Evidence from a National Survey"	2010	McIntosh, C. R., J. F. Shogren and D. C. Finoff	Ecological Economics 3(15): 632-640	http://www.sciencedirect.com/science/article/pii/S0921800909004066
"Outbreak of *Vibrio parahaemolyticus* Gastroenteritis Associated with Alaskan Oysters"	2005	McLaughlin, J.B., A. DePaola, C. Bopp, K. Martinek, N. Napolilli, C. Allison, S. Murray, E. Thompson, M. Bird, J. Middaugh	New England Journal of Medicine 353: 1463-1470	http://www.nejm.org/doi/pdf/10.1056/NEJMoa051594
"Economic Valuation of the Influence of Invasive Alien Species on the Economy of the Seychelles Islands"	2010	Mwebaze, P., A. MacLeod, D. Tomlinson, H. Barois and J. Rijpma	Document	http://www.webmeets.com/files/papers/WCERE/2010/317/PMWEBAZE_WCERE2010.pdf
"The Economics of Alien Invasive Species" (chapter in Invasive Species in a Changing World)	2000	Naylor	Book	http://books.google.com/books?hl=en&lr=&id=hCoJiTo7I3wC&oi=fnd&pg=PA241&dq=naylor,+rosamond+the+economics+of+alien+species+invasions&ots=OLmhr-IsDy&sig=KhOeYoFx579zJ3Wa8j-Pl0x_2ZA#v=onepage&q=naylor%2C%20rosamond%20the%20economics%20of%20alien%20species%20invasions&f=false
"Measuring the Economic Value of Marine Protection Program Against the Introduction of Non-Indigenous Species in Netherlands"	2002	Nunes, P. A L D.	Document	http://www.tinbergen.nl/discussionpapers/02057.pdf
"Can People Value Protection against Invasive Marine Species? Evidence from a Joint TC-CV Survey in the Netherlands"	2004	Nunes, P.A.L.D., J.C.J.M. van den Bergh	Environmental and Resource Economics 28(4): 517-532 DOI: 10.1023/B:EARE.0000036777.83060.b6	http://www.springerlink.com/content/r8172523g8201p76/?MUD=MP
"The Economics of Biological Invasions"	2000	Perrings, C., M. Williamson, E. Barbier, D. Delfino, S. Dalmazzone	Land Use and Water Resource Research 1(3): 1-9	http://www.luwrr.com/uploads/paper01.bak/paper01-03new.pdf

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
Biological Invasion Risks and the Public Good: an Economic Perspective	2002	Perrings, C., M. Williamson, E. Barbier, D. Delfino, S. Dalmazzone, J. Shogren, P. Simmons, A. Watkinson	Conservation Ecology 6(1):1	http://www.ecologyandsociety.org/vol6/iss1/art1/print.pdf
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"Update on the environmental and eocnomic costs assoicated with alien-invasive species in the United States"	2004	Pimentel, D., R. Zuniga, D. Morrison	Ecological Economics 52(3): 273-288	http://www.sciencedirect.com/science/article/pii/S0921800904003027
"Economic and environmental threats of alien plant, animal, and microbe invasions"	2000	Pimentel, D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C.O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, T.Tsomondo	Agriculture, Ecosystems and Environment 84 (2001) 1–20	http://siteresources.worldbank.org/EXTABOUTUS/Resources/gss-economic-environ-threats-ias.pdf
"California Aquatic Nusiance Speicies Management Plan"		Pimentel, D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, T. Tsomondo	Document	http://www.anstaskforce.gov/State%20Plans/CA_SMP_Final.pdf
"Invasion of Coastal Marine Communities in North America: Apparent Patterns, Processes, and Biases"	2000	Ruiz, G.M., P. Fofonoff, J. Carlton, M. Wonham, A. Hines	Annu. Rev. Ecol. Syst. 31:481–531	http://www.limnoreferences.missouristate.edu/assets/limnoreferences/Ruiz_et_al_2000.pdf
"Alaska Aquatic Nusiance Speicies Management Plan"	2002	State of Alaska	Document	http://www.anstaskforce.gov/State%20Plans/ak_ansmp.pdf
"How well do we understand the impats of alien species on ecosystem services? A pan-European, corss-taxa assessment"	2009	Vila, M., C. Basnou, P. Pysek, M.Josesson, P. Genovesi, S. Gollasch, W. Nentwig, S. Olenin, A. Roques, D. Roy, P. Hulme	Frontiers in Ecology and the Environment 8(3): 135-144	http://www.esajournals.org/doi/pdf/10.1890/080083

APPENDIX H

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
"The effect of an aquatic invasive species (Eurasian watermilfoil) on lakefront property values",	2010	Zhang, C. and K. J. Boyle	Ecological Economics online only doi: 10.1016/j.ecolecon.2010.09.011	http://www.eaglelake1.org/environmental_issues/invasive_species/aquatic/milfoil/Zhang%20and%20Boyle%20EE%202010.pdf
"Economic analysis of containment programs, damages, and production losses from noxious weeds in Oregon."	2000	Radtke, H. and S. Davis.	Document	http://www.oregon.gov/ODA/PLANT/docs/pdf/weed_body_a.pdf?ga=t
"Economic Impacts of Invasive Plants in BC"	2009	Frid, L., D. Knowler, C. Murray, J. Meyers, L. Scott	Document	http://69.89.31.205/~refbccom/userfiles/Invasive%20Plant%20Council%20Final%20Rpt%201007-119.pdf
Califorina Aquatic Invasive Species Rapid Repsonse Fund, An Economic Evaluation	2011	Cohen, A. and Cardno ENTRIX	Document	http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=36250
13 Impacts of Invasive Species on Ecosystem Services	2007	H. Charles, J. Dukes	Book	http://dge.stanford.edu/DGE/Dukes/Charles_Dukes_inpress.pdf
"Science and Economics in the Management of an Invasive Species"	2006	Hoagland, P., D. Jin	BioScience 56(11):931-935.	http://www.bioone.org/doi/full/10.1641/0006-3568%282006%2956%5B931%3ASAEITM%5D2.0.CO%3B2
"Assessing the Econmoic, Environmental, and Societal Losses from Invasive Plants on Rangeland and Wildlands"	2004	Duncan, C.A., J.J. Jacetta, M.L. Brown, V.F. Carrithers, J.K. Clark, J.M. DrTomaso, R.G. Lym, K.C. McDaniel, M.J. Renz, P.M. Rice	Weed Technology 18: 1411-1416	http://www.jstor.org/discover/10.2307/3989662?uid=3739512&uid=2129&uid=2&uid=70&uid=4&uid=3739256&sid=21101122838627
"A note on the economics of biological invasions"	2001	Barbier, E.B.	Ecological Economics 39: 197-202	http://papers.ssrn.com/sol3/papers.cfm?abstract_id=296879
"An Analysis of Economic Cost Minimization and Biological Invasion Damage Control Using the AWQ Criterion"	2007	DeAngelo, G., A.A. Batabyal, S. Kumar	Document	http://www.gregorydeangelo.com/Cost_Minimization_using_AWQ.pdf
"On Prevention and Control of an Uncertain Biological Invasion"	2005	Olson, L.J., S. Roy	Review of Agricultural Economics 27: 491-497	http://papers.ssrn.com/sol3/papers.cfm?abstract_id=876734
"Economic Policy for Invasive Species"	2002	Jensen, R.	Document	http://www.nd.edu/~rjensen1/workingpapers/InvasiveSpecies.pdf

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
"Managing invasive species: rules of thumb for rapid assessment"	2005	Leung, B. Finnoff, J.F. Shogren, D. Lodge	Ecological Economics 55: 24-36 doi:10.1016/j.ecolecon.2005.04.017	http://biology.mcgill.ca/faculty/leung/articles/Leung_Rulesofthumb.pdf
"Nonindigenous Aquatic Species Comprehensive Management Plan"	1993	Sinnott, T.J., E. Paul	Document	http://www.dec.ny.gov/docs/wildlife_pdf/noninsp.pdf
"First Report of *Armillaria sinapina,* a Cause of Armillaria Root Disease, Associated with a Variety of Forest Tree Hosts on Sites with Diverse Climates in Alaska"	2009	Klopfenstein, N.B., J.E. Lundquist, J.W. Hanna, M.-S. Kim, G.I. McDonald	Plant Diseases 93(1): 111	http://www.treesearch.fs.fed.us/pubs/34078
"Potential Economic Losses Associated with Uncontrolled Nutria Populations in Maryland's Portion of the Chesapeake Bay"	2004	Maryland Dept of Nat. Resources	Document	www.dnr.state.md.us/irc/docs/00006595.pdf
"Invasive Species, Border Enforcement, and Firm Behavior"	2010	Ameden, H., S. Brody, S.B. Cash, D. Zilberman	Agricultural and Resource Economics Update 13(3): 1-4	http://giannini.ucop.edu/media/are-update/files/issues/v13n3.pdf
"Trade, the Damage from Alien Species, and the Effects of Protectionism Under Alternate Market Structures"	2006	Batabyal, A.A., H. Beladi	Document	https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=MWITSpring2009&paper_id=41
"On the Garden Path: An Economic Perspective on Prevention and Control Policies for an Invaisve Species"	2006	Kaiser, B.A.	Choices magazine 3rd quarter 21(3): 139-142	http://www.choicesmagazine.org/2006-3/invasive/2006-3-03.htm
"Economic Lessons from Control Efforts for an Invasive Species: Miconia calvescens in Hawaii"	2007	Burnett, K., B. Kaiser, J. Roumasset	Document	http://www.uhero.hawaii.edu/assets/JFE.pdf
"On Economic-Cost Minimization Versus Biological-Invasion Damage Control"	2006	DeAngelo, G., A.A. Batabyal, S. Kumar	Book	http://library.wur.nl/frontis/plant_health/03_deangelo.pdf

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
"Bioeconomic management of invasive vector-borne diseases"	2009	Fenichel, E.P., R.D. Horan, G.J. Hickling	Biological Invasions12(9): 2877-2893 DOI: 10.1007/s10530-010-9734-7	http://www.springerlink.com/content/08n5222102202h51/fulltext.pdf
"Risk and Nonindigenous Species Management"	2005	Finnoff, D., J.F. Shogren, B. Leung, D. Lodge	Review of Agricultural Economics 27(3): 475-482	http://biology.mcgill.ca/faculty/leung/articles/Finnoff_risk.pdf
"Robust Inspection for Invasive Species with a Limited Budget"	2006	Moffitt, L.J, J.K. Stranlund, B.C. Field, C.D. Osteen	Book	http://library.wur.nl/frontis/plant_health/02_moffitt.pdf
"The Economics of Terrestrial Invasive Species: A Review of the Literature"	2006	Olson, L.J.	Agricultural and Resource Economics Review 35(1): 178–194	http://ageconsearch.umn.edu/bitstream/10181/1/35010178.pdf
"Spacial Management of Invasive Species: Pathways and Policy Options"	2009	Sanchirico, J.N., H.J. Albers, C. Fischer, C. Coleman	Environ Resource Econ 45:517–535 DOI 10.1007/s10640-009-9326-0	http://www.springerlink.com/content/b8q736717005q221/fulltext.pdf
"The Economics of Pesticides and Pest Control"	2007	Sexton, S.E., Z. Lei, D. Zilberman	International Review of Environmental and Resource Economics 1: 271–326	http://ecnr.berkeley.edu/vfs/PPs/Sexton-Ste/web/pesticides.pdf
"Aggregate Costs and Benefits of Government Invasive Species Control Activities in California"	2006	Sumner, D.A., H. Brunke, M. Kreith	Document	http://aic.ucdavis.edu/publications/Costs-Benefits_govCA-EPDControl.pdf
"Estimated Annual Cost of Invasive Plant Work in California"	2009	Califonia Invasive Plant Council	Document	http://www.cal-ipc.org/ip/research/cost.php
"Estimating Net Losses in Recreation Use Values from Non-Indigenous Invasive Weeds"	2010?	Eiswerth, M.E., W.S. Johnson, J. Agapoff, T.D. Darden, T.R. Harris	Document	http://www.unce.unr.edu/publications/files/nr/2003/SP0310.pdf
"Problems, Predators, and Perception: Management of Quahog (hardclam) *Mercenaria mercenria,* stock enhancement programs in southern New England"	2001	Walton, C.W., W.C. Walton	Journal of Shellfish Research 20(1): 127-134	http://www.biodiversitylibrary.org/pdf2/001662000018776.pdf

Title	Date	Author(s)	Journal Name Vol: pg	Online Link
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