Economic Impacts of Live Wild Animal Imports in the United States

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Defenders of Wildlife

White Paper:

Economic Impacts of Live Wild Animal Imports in the United States

This white paper accompanies the report by Defenders of Wildlife entitled *Broken Screens: The Regulatory System for Animal Imports into the United States*. That full report, this white paper, and other supporting materials are available online at www.defenders.org/animalimports.

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Outline

List of abbreviations

AI	Avian influenza
APHIS	Animal and Plant Health Inspection Service, USDA
BSE	Bovine Spongiform Encephalopathy (mad cow disease)
CBA	Cost-benefit analysis
CDC	Centers for Disease Control and Prevention, U.S. Department of Health and Human Services
COI	Cost of illness
CS	Consumer surplus
END	Exotic Newcastle disease
ERS	Economic Research Service, USDA
FAO	U.N. Food and Agriculture Organization
FDA	Food and Drug Administration, U.S. Department of Health and Human Services
FIRRM	Foodborne Illness Risk Ranking Model
FMD	Foot-and-Mouth disease
FWS	Fish and Wildlife Service, U.S. Department of the Interior
FY	Fiscal year
GAO	General Accounting Office, U.S. Congress
HPAI	Highly pathogenic avian influenza
IUCN	International Union for the Conservation of Nature
n/a	Not available
OECD	Organization of Economic Cooperation and Development
OIE	World Organization for Animal Health
OTA	Office of Technology Assessment, U.S. Congress
PS	Producer surplus
SARS	Severe acute respiratory syndrome
TEV	Total economic value
UN	United Nations
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WHO	World Health Organization
WN	Wet Nile
WNV	West Nile virus
WTP	Willingness to pay

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Executive summary

The U.S. legally imports several hundred million individual (individually-counted) live wild animals each year, and over one thousand tons of additional wild animals imported in bulk. Because of the enormous size of the trade and the variety of applications in which imported live animals are used, these imports generate sizeable economic benefits in many sectors of the U.S. economy.

However, these benefits come at a significant cost. Some imported animals escape or are intentionally released and become invasive, causing damage to human structures, crops and livestock, and natural resources and contributing to the endangerment or extinction of native species and communities. Imported animals also constitute a major pathway for the introduction of zoonotic diseases into the U.S., that is, of diseases that are transmissible between animals and humans. Examples of diseases for which internationally traded live animals serve as vectors include bovine spongiform encephalopathy ("mad cow disease"), exotic Newcastle disease, monkeypox, reptile-associated salmonellosis, foot-and-mouth disease, avian influenza, swine fever, and heartwater disease.

In this study, we review the literature to gauge the overall economic impact of live animals imported to the U.S. in 2004, the most recent year for which detailed data on live wild animal imports are available. We also generate original cost estimates for some impacts not available in the existing literature. In doing so, we mainly focus on the costs associated with the import trade. A full analysis of the benefits and costs of live animal imports is beyond the scope of our inquiry and would not generate much valuable information - the question is not whether or not benefits from live animal imports are larger than costs. Rather, what is of interest is the magnitude of the costs of this trade, and whether or not opportunities exist to substantially reduce them. By focusing mainly on the cost side, we provide an indication of the overall magnitude of welfare gains that could be realized by correcting the key weaknesses in the current regulatory system.

Quantifying the full economic impacts associated with live animal imports is a daunting task. The complexity of such an analysis stems not only from the wide range of impacts associated with imported animals, but also from the fact that many impacts are not sufficiently well documented to allow economic valuation. Even for those impacts for which quantitative estimates exist, economic valuation is often difficult because many of these impacts involve non-market values that are very costly to estimate.

As a result, the scope of our analysis is limited. We include estimates of the resource damages caused by some non-native invasive species that were intentionally introduced to the U.S. We also include estimates of the costs imposed by several diseases that entered the country through intentional live wild animal imports. Many of these cost estimates are only partial representations of the full economic costs caused by animal imports because they only include the *market* value of the damaged resources.

Despite these limitations in the scope of our analysis, the size of the documented costs imported live animals impose on the U.S. is staggering. Resource damages caused by intentionally introduced non-native animal species in the U.S. alone amount to an estimated $35 billion per year. However, these costs represent the total impact from the current

populations of non-native alien species intentionally introduced for which some information on damages is available. Only a small share of this total cost is attributable to those specimens of these species introduced during 2003-2004, the period analyzed in our study. Importantly, this resource damage estimate does not include the economic value of negative impacts of invasive imported animals on native biodiversity.

Estimated damages also do not include the costs from diseases entering the country through the live wild animal trade. In 2004, the costs associated with major diseases that either conclusively (exotic Newcastle disease) or potentially (West Nile virus and avian influenza) entered the U.S. through live wild animal imports in 2003-04 or for which imported live animals acted as a reservoir for infections (reptile-associated salmonellosis) was an estimated $397 - $911 million (Table ES-1). These costs include lost productivity and human loss of life, some medical costs, poultry losses, lost export revenues from trade restrictions imposed after disease outbreaks, and surveillance and eradication campaigns by some federal agencies. However, given that for each of the diseases included in our analysis information on some impacts is missing, the estimated damages from each of these diseases likely represent underestimates of actual damages.

Table ES-1: Low and high estimates of costs to the U.S. of diseases associated with imported live wild animals, 2004

	Low cost estimate (2004$)	*High cost estimate (2004$)*
Costs of diseases either *potentially or definitively* linked to 2003-04 live wild animal imports *	901 million	911 million
Costs only of diseases considered *definitively* linked to 2003-04 live wild animal imports *	397 million	407 million

Note: *Cost of diseases includes only those diseases for which cost estimates were compiled in this study.

In addition to these current impacts, live wild animal imports are seen as being of particular concern to public health because they are seen as a major pathway for the future introduction of emerging and still undiscovered zoonotic pathogens, that is, pathogens transmissible between animals and humans. Out of 1,415 identified infectious organisms known to be pathogenic to humans, 61 percent are zoonotic, and zoonotic pathogens are more likely to be associated with emerging diseases. Zoonoses have been responsible for eleven of the last twelve significant human epidemics. They are of particular concern also because they are widely seen as the group of infectious diseases whose geographic range is going to expand most in the future. As a result, the potential economic and public health threat live animal imports constitute is only expected to increase in the future. Improved safeguards against dangerous live wild animal imports are urgently needed to reduce the likelihood of occurrence of major future human epidemics in the U.S.

Many of the damages imposed by live animal imports likely could be substantially reduced. These damages principally result from failures of the current system of import regulations to screen out invasive or otherwise harmful species, including disease carriers. As a result of these failures, the current system of live animal imports promotes a situation that is both economically inefficient and inequitable. It is inefficient because large net benefits could be

gained by society as a whole from correcting the failures of the import system. It is inequitable because it imposes a large share of the damages associated with live animal imports on third parties that are neither directly nor indirectly involved in live animal imports and that are not the main beneficiaries of these imports, or that do not benefit from these imports at all. Some of these costs are incurred either by individuals (people and firms) directly, in the form of medical expenses, lost income, premature death, and pain and suffering from infectious diseases carried by imported wild animals, or from infrastructure and resource damages caused by these imports. Others are borne indirectly in the form of tax payments to finance control efforts by local, state, and federal agencies.

The economic inefficiency and the inequity inherent in the current live animal import system both could be reduced substantially through eminently feasible measures. Inefficiency and equity both result from the failure of the current system to adequately internalize negative externalities (or third-party impacts) of animal imports. Society as a whole could benefit enormously if importers and users of imported live animals were forced to confront the full costs, or at least a larger share of the full costs, associated with these imports.

The prescription to overcoming the shortcomings of the present system is fairly straightforward: what is needed is a comprehensive risk assessment based on a thorough pre-screening of all imported species, coupled with substantially improved reporting requirements, fines that are sufficient to deter violations (accompanied by associated higher fines or criminal prosecution for illegal importation to avoid pushing more imports underground), and an effective inspection and quarantine regime. These efforts should be financed through fully cost-covering inspection and quarantine fees and the imposition of corrective taxes on sales of imported live animals or, alternatively, tariffs on imported live animals. Pre-screening of all imported species through a comprehensive risk assessment is not only technically feasible and would generate large net economic benefits, but initial efforts that could serve as a basis for a full risk assessment of live animal imports to the U.S already have been completed.[1] Implementing a strong continuous risk assessment program is feasible and would be economically beneficial. It also would seem a wise investment to reduce the risk of costly surprises from the importation of future emerging diseases.

[1] See Defenders of Wildlife (2007).

I. Introduction

Every year, international trade flows move billions of live animals across national borders. The U.S. alone imported a total of almost 1.1 billion individually-counted wild (non-domesticated) animals during the five year-period from 2000 to 2004, and an additional 5,200 tons of bulk wild animals (Defenders of Wildlife, 2007).

Such massive cross-border movements of animals clearly have economic implications, both positive and negative. On the positive side, the trade generates employment and earnings in sectors associated with the live animal trade in both exporting and importing countries. On the negative side, imported non-native animals may cause major economic damages if they become invasive, destroying or damaging infrastructure, crops, and natural resources. Invasive animals also represent a threat to the preservation of native biological diversity. In fact, invasives (animals and plants) are considered the second most important cause for global biodiversity loss, after land cover change through habitat destruction, degradation, and fragmentation (Perrings et al., 2000). The Global Biodiversity Assessment concluded that invasives generally have negative effects on both species and genetic diversity at local and global levels. These negative effects include the deletion of indigenous species through predation, browsing or competition; genetic alteration of indigenous species through hybridization; and alteration of ecosystem structure and function including biogeochemical, hydrological, and nutrient cycles, soil erosion, and other geomorphological processes (Perrings and Lovett, 1999). It is estimated that over 40 percent of the species listed as threatened or endangered in the U.S. are at risk primarily because of invasive species (Wilcove et al., 1998).

In addition to the resource damages and negative impacts on ecosystem health and native species diversity, imported wild animals also constitute a major pathway for the introduction into a country of zoonotic diseases, that is, diseases transmissible between humans and animals. Examples of diseases for the cross-border spread of which the live wild animal trade serves as a vector include exotic Newcastle disease, monkeypox, reptile-associated salmonellosis, avian influenza and heartwater disease. In addition to the direct health effects of zoonotic pathogens on persons and animals, disease outbreaks resulting from wildlife trade have caused hundreds of billions of dollars in economic damages globally (Karesh et al., 2005).[2] Animal diseases introduced by trade or movement of animals historically have had dramatic economic impacts on the affected countries, regions, or whole continents, and the devastating consequences associated with introduced animal diseases remain a threat to livestock and human health in the U.S. (Torres, 1999). Live animal imports are of particular concern to public health in the future because they are expected to be a major pathway for the introduction of emerging and still undiscovered zoonotic pathogens. Out of 1,415 identified infectious organisms known to be pathogenic to humans, 61 percent are zoonotic, and zoonotic pathogens are more likely to be associated with emerging diseases (Taylor et al., 2001).

[2] For example, Newcomb (2003) estimates that outbreaks of emerging infectious diseases in humans and livestock caused over $100 billion in damages globally during 1993-2003.

The large economic costs associated with invasive animals and animal-borne diseases, and the potential for even larger future costs from animal imports, make it imperative that these imports be conducted in such a manner as to balance the benefits and costs they generate for society. Currently, this balancing is not occurring, for several reasons that will be explored in this paper.

Economic analysis has much to offer for achieving a more efficient and equitable regime of live animal imports. For one, it can contribute to quantifying the positive and negative impacts from animal imports. More importantly, it can analyze the potential damages from future invasions and imported zoonotic diseases. Until recently, most economic (and biological) research on invasives focused on quantifying impacts of existing invasives rather than analyzing the potential for future invasions and their impacts (Kolar and Lodge, 2002). That focus is beginning to shift, however.

A. Scope of the study

Since European settlement, hundreds of animal species have been introduced into North America, both intentionally and unintentionally (Pimentel et al., 2005; OTA, 1993). While many of these species are causing sizeable economic impacts today (Pimentel et al., 2005), a large portion of these impacts must be attributed to imports that occurred decades or even centuries ago. The purpose of this report is to highlight the benefits that can be gained (or, conversely, the costs that can be avoided) by improving the system of import regulations governing the importation of live animals. Therefore, the focus of our inquiry is limited to assessing the impacts associated with present and future animal imports. As a result, we need to distinguish between the total costs society currently incurs from all species not native to U.S. territory, and that portion of these costs that actually is caused by present imports. The former have been analyzed in the literature (Pimentel et al., 2005; OTA, 1993); the latter has not, at least not in a comprehensive manner. The present study is intended as a companion document for the report *Broken Screens: The Regulatory System for Animal Imports into the United States* (Defenders of Wildlife, 2007). Consequentially, we limit our focus to match that of the Defenders of Wildlife study, including only intentional, legal, live animal imports. We compile and develop estimates of the costs and benefits of particular impacts associated with live animal imports for the year 2004, the most recent year for which detailed import data are available and the last year covered in the companion study.

In the next part of the paper, we begin by presenting the framework for our economic analysis of live animal imports into the U.S. Part Three presents the findings of our literature review on the economic impacts of live animal imports, and develops preliminary estimates for some impacts for which such estimates do not exist in the literature. Part Four discusses the shortcomings that characterize the current system of live animal imports into the U.S. and provides suggestions as to how these shortcomings can be overcome.

II. Economic analysis framework

Economic analysis can play several useful roles in policy evaluation. At the most basic level, economic analysis either can help in the setting of policy goals, or it can serve to identify ways to achieve given policy objectives at least cost. In the first case, the analysis takes the form of cost-benefit analysis; in the second, that of cost-effectiveness analysis. Cost-benefit analysis can inform the setting of policy goals by identifying the economically optimal level of a program or activity, that is, the level at which the net benefits to society from that program or activity are maximized. Cost-effectiveness analysis, on the other hand, is appropriate when goals are already set on the basis of non-economic considerations, such as health standards or other regulations, and simply identifies among various alternative means of achieving a given goal that which does so at least cost. Finally, economic analysis can serve to simply document the size of a certain outcome, positive (benefit) or negative (cost).

The strength of economic analysis lies in the fact that it makes the diverse impacts of an action comparable by expressing them using a common denominator, usually a monetary metric like the dollar. This ability to condense diverse impacts into an easily understandable numeric expression makes economic analysis attractive to decision-makers.

Though conceptually straightforward, application of economic analysis to concrete decision problems often is made difficult by the lack of required, or reliable, data. In addition, the monetary values economic analysis assigns to impacts in the forms of changes in the quantities of goods and services are based on individuals' preferences. The latter often are neither easy to observe nor easy to quantify accurately, and in many cases their estimation requires the application of valuation approaches that incorporate a number of assumptions in order to overcome information constraints. This is especially true when the action being evaluated impacts goods and services that are not directly, or not at all, traded in markets, such as species or whole ecosystems.

All of these complicating factors are present in the case of the economic analysis of live animal imports in general, and of imports of invasive animals in particular. As a result, while the framework of an analysis of animal imports is the same as that of any other economic analysis (Cochran, 1992)[3], no comprehensive economic analysis of the value of live animal imports has been carried out to date.

There are several possible applications of cost-benefit analysis (CBA) to the topic of live animal imports. For example, CBA could be used to estimate the net impact on the U.S of all imported species. The results of such an analysis would be of limited policy use, however, because many invasions are irreversible (Mack et al., 2000), as are their consequences if these involve for example native species extinctions. More usefully, CBA could be used to evaluate the economic impacts of eradicating (where possible) or containing a particular invasive, or of preventing its entry into the country in the first place. Many such analyses have in fact been carried out (for compilations of studies, see OTA [1993] and Hill and Greathead [2000]). Finally, CBA could be used as part of a risk assessment to evaluate the economic impacts of restrictions on the importation of live species, such as the institution of a pre-

[3] Cochran's (1992) outline of the steps involved in a cost-benefit analysis of non-indigenous species is reproduced in OTA (1993) (see OTA, 1993, Box 4-D), which is accessible online (see references for the link).

screening system (see for example Keller et al., 2007).

The last application of CBA is perhaps the most useful because implementation of an effective import pre-screening system offers the largest potential of reducing the negative impacts from future imports of species that become invasive or are capable of causing disease outbreaks in humans and/or animals. However, it is also the most challenging, because of the multiple points at which uncertainty enters into the analysis. A CBA of pre-screening programs needs to explicitly address the uncertainty associated with the occurrence of potential future invasions and disease outbreaks. In most cases, the probability of this occurrence is unknown, as is the probability of different magnitudes of associated economic, human health, and ecological damages (Horan et al., 2002).[4]

Assessments of potential ecological damages in particular are characterized by non-linear responses, thresholds, and irreversibilities exhibited by natural systems. Though not necessarily insurmountable (Horan et al., 2002; Keller et al., 2007), these challenges do significantly complicate the application of economic analysis (Evans, 2003).[5] In addition, the likelihood of the pre-screening process actually identifying correctly potential future invaders also is not characterized by a known probability distribution. Scientific knowledge about the invasiveness potential of many species is limited. A necessary first step towards addressing the last problem is the comprehensive characterization of known invasives worldwide. The preliminary risk screening of animal species imported into the U.S. recently completed by the IUCN Invasive Species Specialist Group (2007) could serve as a starting point for such a comprehensive characterization (Defenders of Wildlife, 2007).

We do not conduct a CBA of species imports or import controls here because that is beyond the scope of the present study. Rather, we compile and modify existing estimates of the economic impact of invasives and generate some original estimates for impacts omitted in those studies. We document some of the costs and benefits associated with live intentional animal imports for 2004, the most recent year for which data on live animal imports are available. Our main focus lies on the costs associated with this import trade. A full analysis of the benefits and costs of live animal imports, in addition to being beyond the scope of our inquiry, would not generate much valuable information since the argument is not whether or not all live animal imports should be stopped. Rather, the challenge at hand is to devise an import system that allows the maximization of the net benefits to the U.S. from animal imports or, at a minimum, an increase in net benefits compared to the current, highly imperfect, state of managing those imports. Most current restrictions on live animal imports into the U.S. are based on specific biosecurity concerns and thus presumably generally are justified either on the basis of economic or non-economic public policy concerns. Thus, there seems little room to affect the benefits side of imports through easing of existing

[4] Referring specifically to the challenge of assessing the potential impacts of human diseases of animal origin - one of the impacts associated with imported animals - the WHO, FAO, and OIE (2004, p. 29) describe the problem well as being "characterized by (i) lack of information on the disease in terms of rates of infection and the links between animal and human cases of the disease (BSE is a prime example of this), (ii) high levels of risk in that these diseases may potentially result in very high economic impacts (e.g. resulting from pandemics of high animal and/or human mortality), (iii) given (i), a high level of uncertainty in that the probabilities of different disease/economic outcomes are unsure (including the effect of disease control measures)."

[5] In cases where extreme impacts are possible, it may be better to move from a quantitative to a more qualitative economic analysis and to base policy on the precautionary principle (van den Bergh, 2004).

import restrictions. On the other hand, the cost side of imports shows room for substantial reductions in negative impacts through well-designed policies, using both long-established and novel approaches. By focusing mainly on the cost side, we provide an indication of the overall magnitude of welfare gains that could be realized by correcting the key weaknesses in the current regulatory system.

In the remainder of this section, we present the types of benefits and costs associated with live animal imports and discuss the types of economic values associated with these impacts, as well as the approaches commonly used to quantify these values in monetary terms.

A. Classification of economic impacts associated with live animal imports

1. Positive vs. negative impacts

Imported live wild animals directly or indirectly affect many sectors of the U.S. economy (Table 1). They generate economic benefits by increasing resource productivity or the quantity or quality of outputs, or by reducing input costs. Part of the resulting benefits are captured by producers in the form of increased profits, part by consumers in the form of increased consumer surplus from reduced product prices or increased utility of consumption.

The majority of imported live wild animals are used as pets, including fish in home aquaria (Defenders of Wildlife, 2007). As such, they directly support sales and jobs in the multi-billion dollar pet supplies and services industries. Pets themselves contribute to the physical and emotional well-being of their owners. Imported animals are also used in various parts of the recreation industry. For example, they support a growing exotic game ranch industry, and public and private zoos and aquaria. Selected species also have been, and likely occasionally continue to be, imported to be used in stocking lands and water bodies for game purposes. In addition, imported species are used in some parts of the agri- and aquaculture industries, principally to improve stock productivity through selective breeding or to control pests. Imported animals are also used in the biomedical research industry, though most animals used in that industry are domestically produced (California Biomedical Research Association, 2003; Research Resources Information Center, 2003). Finally, live animals are imported for use in the food products (packaged foods) and gastronomic industries (restaurants).

These positive impacts, however, represent only one side of the equation. Animal imports also impose high costs on society. Some imported animals escape confinement, accidentally or through intentional release, and become invasive. Invasives negatively impact native species or whole ecosystems, imposing costs on society in the form of species conservation efforts, surveillance, containment, or eradication efforts, loss of ecosystem services (resulting from invasives' impacts on ecosystem structure and functioning), and loss of scenic amenities and quality of recreational experiences. For example, introduced Asian carp degrade water quality, causing negative impacts on recreational fisheries and non-extractive recreation activities and the local communities dependent on these activities as well as recreation-related industries. Invasive animals also damage production infrastructure, as in the case of the nutria (*Myocastor coypus*) or the Asian clam (*Corbicula fluminea*), both of which were imported and introduced intentionally. Invasions by one species also may facilitate the spread of other invasives. For example, the invasive nutria, in addition to damaging water-

retention and flood control levees, reservoir dams, irrigation ditches, roadbeds, and houses, eroding stream and lake banks, and crops, also has accelerated the spread of invasive plants like the purple loosestrife in wetland ecosystems, with resulting deleterious impacts on marshes and migrating waterfowl (APHIS, 2005; Bounds, 2000).

Table 1: Benefits and costs associated with live wild animal imports

Benefits	*Costs*
Pets (mammals, birds, reptiles, amphibians, fish, insects, etc.)	Human diseases (emotional and treatment costs; reduced labor productivity; lost wages)
Biomedical research	Livestock & aquaculture diseases - resource productivity or marketability - damages to facilities
Livestock & aquaculture industries (breeding stock enhancement or stocking, pest control) - higher productivity - lower input costs	Non-livestock animals disease - species endangerment - recreational uses (sport/game species) - commercial uses (e.g., fisheries, agri- and horticulture – pollinated crops[bees])
Food industry - live animals inputs for restaurants - live animal inputs to processed foods	Plant impacts from plant disease (pathogens) or consumption (animals) - Crop losses - other vegetation losses (e.g., forests) or reduced marketability/use of products
Recreation - Entertainment (aquaria, zoos) - Stocking of lands or water bodies for sport/game purposes (hunting, fishing)	Invasiveness (predation/competition with native species) - species endangerment (passive use and biodiversity use values) - ecosystemic changes (visual amenities, tourism; ecosystem services)
Agriculture/conservation - crop pollination* - biological pest control	Management and control of invasives - import screening/inspections - identification and control of invasions

Notes: *Limited. Importation into the U.S. of the main crop pollinating insect, the European honey bee, has been illegal since 1922. However, honey bees are imported for research purposes.
Sources: OTA (1993); Pimentel et al. (2005); WHO, FAO, and OIE (2004).

Imported animals also serve as hosts for a number of common or emerging infectious diseases of humans or animals, and they may carry other species that serve as vectors for these diseases. These diseases cause low-level chronic infections and occasional outbreaks, both of which carry high costs in the form of medical expenses and reduced quality of life, productivity losses, loss of human and animal life, and negative animal welfare impacts. Infectious diseases of livestock also reduce the productivity of livestock or aquaculture operations, may reduce the (actual or perceived) quality or safety of food, and may result in restrictions on agricultural exports.

Because of the presence of both positive and negative impacts from animal imports, the relevant gauge of a species' economic impact on society as a whole is its net benefit (or cost).

2. Types of economic values associated with impacts

As shown in Table 1, imported animals can have a wide range of costs and benefits. The types of economic values associated with a particular impact vary with the type of good or service impacted. In general, when impacts affect goods with mainly utilitarian character, such as produced infrastructure or goods, the value of the impacts consists mainly in the lost uses of the product, for which the market prices of those goods generally are good indicators. However, when human health, the health of companion animals, or natural resources such as species, ecosystems, or scenic landscapes are impacted, then what is lost is more than just use value. In those cases, the actual value individuals associate with the losses cannot be determined using market prices, because these goods generally are not traded in markets. For example, humans may value a scenic landscape or charismatic species irrespective of their "use" of that landscape or species (e.g., in the form of recreation), simply for knowing they exist and are passed on to posterity. Such values in economics are referred to as passive or non-use values (Krutilla, 1967). Or people may value retaining the option of using in the future a resource they do not presently use. Both passive use and to some degree option values are not reflected in the market prices of goods or services, because they do not result in market transactions at all (passive uses) or often only may do so at some point in the future (option values). Finally, if impacts of imported animals reduce the services a species or ecosystem provides to society, such as pollination of crops or provision of clean water, the value of that impact may be estimated using market prices, but the impact generally is difficult to quantify. The reason for this is that one needs to identify all the marketed outputs that benefit from that ecosystem service (in this example, pollination-dependent crops; clean drinking water or irrigation water) and then observe the changes in the quantities and prices of those outputs in order to estimate the value of the lost ecosystem services. Both of these can be difficult to measure.

In order to correctly assess the value of an impact, one has to consider the total economic value (TEV) of the affected resources. This value comprises direct, ecosystem service and passive use values associated with affected goods (including natural resources) and services (Fig. 1).

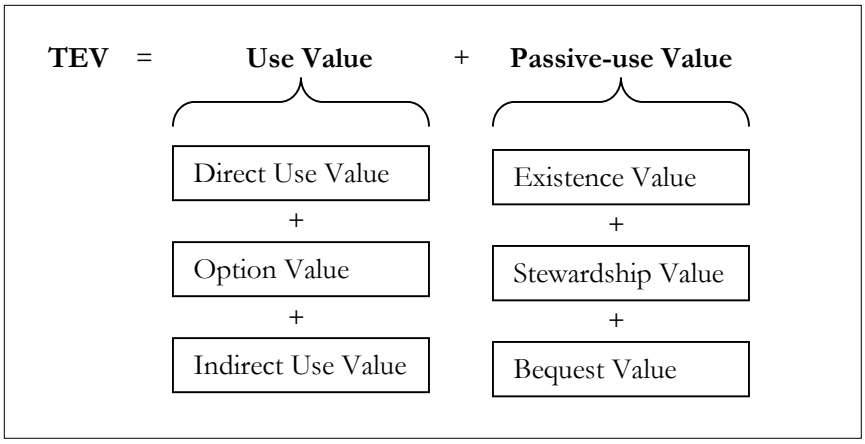

Figure 1: Components of the total economic value (TEV) of a good or service

Distinguishing between the various components of total economic value is not of purely theoretical interest. Rather, it is useful, and indeed often necessary, when quantifying the economic value of a resource in monetary terms. The reason for this is that of the many different approaches economics offers for the quantification of value, not all are suitable for quantifying all values. Hence the importance of determining clearly what types of values are associated with particular uses of a resource.

3. Quantification of economic values associated with impacts

In economics, value is measured by individuals' willingness to pay (WTP). WTP is defined as the maximum amount of resources an individual would be willing to give up in order to obtain a particular good or service, or the minimum amount in compensation she would demand in order to give up that good or service.[6] For example, if someone is willing to spend up to, but no more than, five dollars to acquire a particular object, that person's willingness to pay (WTP) for that object is five dollars.[7]

For mainly utilitarian goods traded in markets, market prices generally serve as a reasonably good indicator of individuals' WTP for those goods. As long as the impacts are sufficiently small not to affect market prices, their economic value (cost or benefit) can be quantified using the market price and quantities of the lost (or additional) goods or service resulting from the impact. If impacts affect supply or demand of a good or service to the degree that prices change, then the price changes must be incorporated into the analysis. For goods and services not directly traded in markets, such as many components of the natural environment, approaches other than the use of market prices must be employed to estimate their economic value. The development and refinement of techniques for the economic valuation of environmental goods and services during the past four decades has been a primary focus of the subdisciplines of environmental and natural resources economics. Thanks to the advances made it is now possible to estimate the monetary value of most types of environmental benefits (Cropper, 2000). However, application of these valuation techniques is costly.

Figure 2 shows the approaches available for estimating the economic value of environmental assets, for each type of value – direct use, indirect use, and passive use. At the most basic level, all valuation approaches rely either on individuals' revealed or stated preferences.[8] Revealed preferences approaches are based on people's observed behavior and are commonly employed to measure individuals' WTP for marketed goods and services. Stated preference approaches estimate the value of a good or service by asking people directly for their WTP for that good or service. They are the only approaches available for valuing goods and services that are not traded in markets or that have substantial non-use values. Although

[6] The two approaches, willingness to pay (WTP) and willingness to accept (WTA) compensation, generally yield different estimates of economic value for a good or service. Studies have shown that individuals' WTP to obtain a hypothetical gain (benefit) is generally substantially smaller than their WTA a hypothetical loss (Adamowicz et al., 1993; Haneman, 1991). This difference is caused by the psychological impact of a difference in the nature of the ownership regarding the hypothetical resource change, often referred to as the endowment effect (Kahneman et al., 1990), and by the fact that income constraints bind WTP, but not WTA.

[7] WTP and economic value are commonly expressed in monetary units. However, money is simply a convenience metric. WTP can be expressed in any unit.

[8] For an excellent overview over economic valuation techniques, see Freeman (2003).

sometimes considered with skepticism, stated preference approaches, if applied rigorously, yield valid WTP estimates (Arrow et al., 1993; Hanemann, 1994; Carson et al., 1996, 2001).

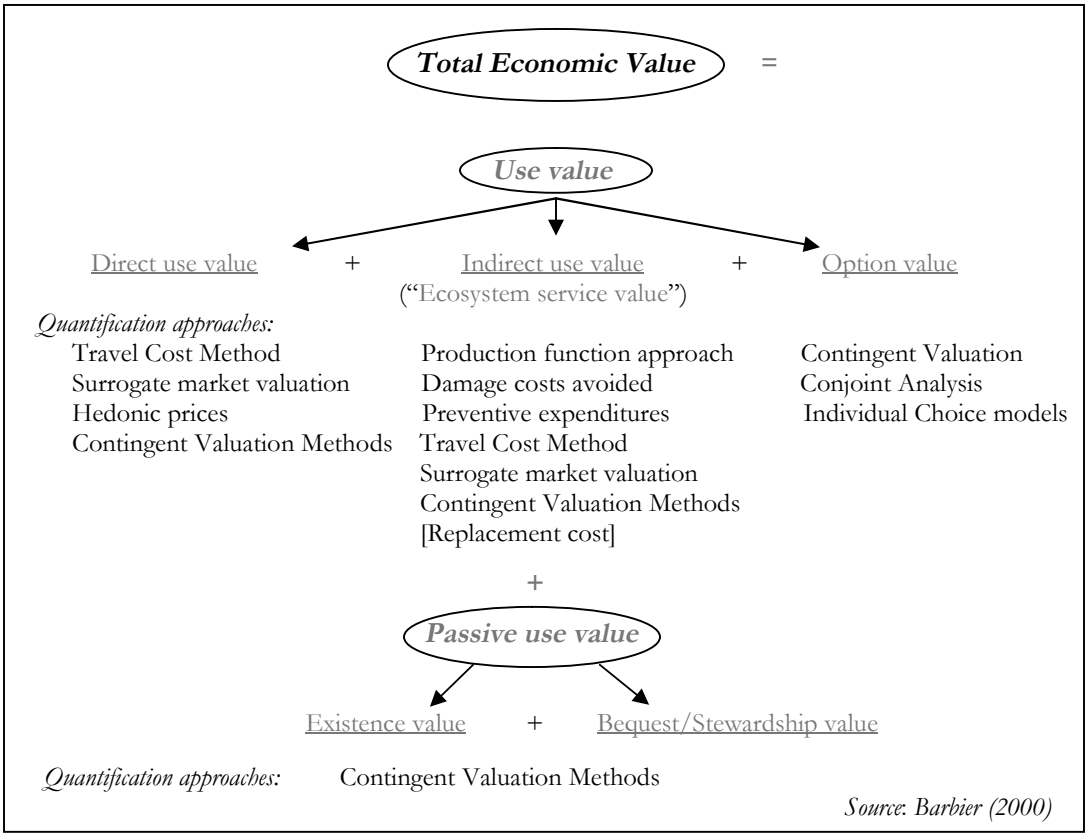

Figure 2: Categories of economic values of ecosystems and available valuation approaches

Live animal imports cause impacts on marketed goods and services as well as on goods and services not marketed (see Table 1). Assessing the full economic value of impacts therefore requires application of both revealed and stated preference approaches. Importantly, the choice of valuation approach determines the comprehensiveness of the resulting value estimates in cases where impacts affect passive use values.

B. Data requirements

The data requirements for a comprehensive analysis of the economic values associated with the impacts of live wild animal imports are substantial. For each of the impacts listed in Table 1, information is needed on the aggregate demand (WTP) and supply functions for all goods and services affected directly or indirectly by live animal imports. In addition, quantification of the value of non-market impacts, such as species extinction or endangerment or pain and suffering associated with sickness from animal-borne human diseases, require information on individuals' WTP for avoiding those impacts or their willingness to accept compensation for suffering those impacts. In some cases, available data from existing studies may be used to value these impacts. In others, original research is

needed to generate this information.

If the analysis aims to assess the value of potential future impacts or the value of implementing an import pre-screening system, then additional complexity arises from the uncertainty associated with future invasions and their impacts as well as the effectiveness of the screening system.

Basing estimates of the impacts associated with live animal imports on observed, direct impacts like those shown in Table 1 yields a first approximation of the value of impacts. However, such a partial equilibrium approach does not take into account the reactions in the rest of the economy to these initial, direct impacts. To estimate the full impacts on the economy would require application of an appropriately specified and validated general equilibrium model.

III. Review of findings

In this section, we present partial estimates of the benefits and costs associated with live wild animal imports based on available data. An extensive literature review showed that information on the economic values associated with the live animal trade is scarce, on both the benefit and cost sides.

A. Actual impacts

1. Benefits associated with live wild animal imports to the U.S.

The average annual declared wholesale value of intentional legal live wild animal imports to the U.S. during 2000-2004 was $109 million (Defenders of Wildlife, 2007). The market value of these imports is undoubtedly higher, for two reasons. First, importers have an incentive to under report the value of shipments to reduce import duties. In addition, the majority of all imported live animals end up as pets (including aquarium fish) in private households. These are purchased at retail prices, which lie above wholesale prices.[9]

In any case, the sale price of imported animals is not a meaningful indicator of their overall economic value. Price is a correct measure of the economic value of a product only if it equals the consumer's maximum willingness to pay (WTP) for the product. In most cases, this condition is not met for live animals. For example, many pet owners likely would be willing to pay substantially more to acquire these animals than their asking price. Likewise, animals used as inputs to other production processes, such as in the biomedical industry, recreation industry (stocking of game birds, fish, and mammals; zoos, and aquaria), or food industry generally also create surplus value in those uses, which is not reflected in the animals' market price. This can be expressed easily with the help of a simple diagram.

Figure 3 shows a market for a generic good, say, an imported animal. The supply (*S*) of the good is a positive function of production cost (*PC*), indicating that higher prices will bring forth increased supplies, while the demand (*D*) is a negative function of the price of the good, indicating that demand increases with a fall in price. The quantity of the good sold is defined by the market-clearing price p^* at which demand equals supply. In fact, of course, there are many different markets associated with live animals. However, for the purposes of our analysis, we will consider a generic market that can be thought of as the sum of all markets related to imported live animals.

The market value or revenue of imported animals, defined as the transacted quantity of animals multiplied by the market price p^*, is graphically represented by the sum of the producer cost (the cost to the final seller of supplying the imports animal or related products to the consumer), indicated by the area *PC* in Figure 3, and the producer surplus, or profit, indicated by the blue-shaded area, *PS*. The producer cost includes prices paid to importers and wholesalers, as well as the sellers' operating costs associated with the sold animals. As such, it does not represent a benefit to the seller. Only the producer surplus portion of the market value of the imported animals constitutes a net benefit to the seller from the imports. Likewise, the consumers (or owners in the case of pets) of imported animals receive benefits from their consumption (or ownership) that are higher than the price paid for the animals.

[9] The size of the wholesale-retail spread depends on the particular industry.

This consumer surplus (*CS*) is the amount buyers would have been willing to spend on obtaining the animals above and beyond the price actually paid, and is indicated by the yellow-shaded area in the figure.

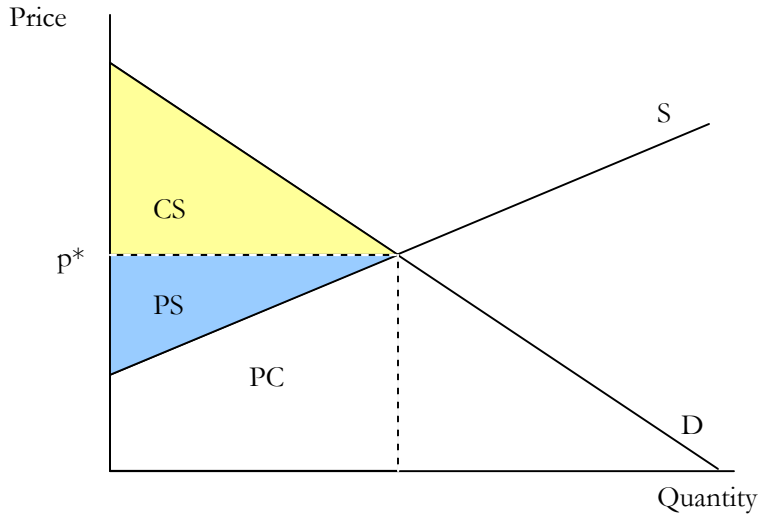

Figure 3: Diagrammatic representation of the live animal import market

The total economic value of the imported animals is indicated by the consumers' total WTP for the imported animals, equivalent to the sum of producer, consumer surplus and production cost. This is the maximum total amount consumers would be willing to pay for the imported animals. However, the net benefit to society from these imports is smaller than the TEV, because society has to expend scarce resources in the amount of the production cost, or *PC*, to acquire the imported animals. These resources could have been devoted to other welfare-enhancing uses therefore represent the opportunity cost of the imported animals. They do not represent a welfare increase or net benefit to society. Rather, the net benefit to society from animal imports is the difference between the total economic value of the imported animals and their cost – namely, the sum of consumer (*CS*) and producer surplus (*PS*).

Unfortunately, while a number of academic and informal surveys have been conducted whose results demonstrate that many pet owners receive emotional and physical benefits from their animal companions (which are not reflected in the pets' purchase prices), our literature search did not turn up any quantitative estimates of the size of these benefits in economic terms.

In addition to the value imported animals generate directly as pets and as inputs in certain industries, they also support part of the large pet supplies (food, drugs, care products, housing, e.g., aquaria, terraria, cages and associated equipment) and services (e.g., veterinary, temporary shelter, grooming) industries in the U.S. In 2004, pet industry expenditures in the U.S. totaled $34.4 billion (APPMA, 2007), of which approximately five percent, or $1.7 billion, was accounted for by live animal purchases. Based on the ratios of the declared wholesale value of imported live animals ($109 million in 2004) and the total value of domestic live animal pet sales, and taking into account that declared wholesale value is lower than final retail sales value, legally imported live animals accounted for around ten percent,

or $3.3 billion, of the total value of U.S. pet industry sales. A more relevant measure from a welfare accounting perspective are the net benefits generated by the pet industry. While no information is available on the aggregate profit margin of the pet supplies and services industry, assuming a reasonable ten percent profit margin would suggest that imported live animals generated pet industry net benefits of around $330 million in 2004.[10]

While most imported animals are used in the pet trade (Defenders of Wildlife, 2007), imported animals also are used as inputs in several industries, such as the biomedical, recreation, food and agricultural industries. We were unable to identify studies that provide information on the value imported animals generate in those industries. The main reasons for this lie in the difficulty of identifying products the production of which involves use of imported live wild animals, and the estimation of the portion of the gross (sales) or net value (producer surplus) generated in those industries that is attributable to imported live animals.[11]

The literature provides many examples of the value of non-native animal species for recreational and agricultural uses (see OTA, 1993). Besides species used for commercial livestock production, perhaps one of the highest-value cases in agriculture is the use of honey bees. Honey bees are an important, and in some case the predominant or only pollinator for many agricultural crops.[12] The value of pollination services bees provide to U.S. agriculture is estimated at around $15 billion per year (Suszkiw, 2001). In addition, honey bees produced honey worth almost $200 million in 2004 (ERS, 2006). However, European honey bees were first introduced to North America by European settlers in the 17th century. Live honey bees currently may be imported from Australia, Canada and New Zealand (Defenders of Wildlife, 2007, Appendix C), but honey bees imported in 2004 likely accounted for a negligible proportion of overall U.S. crop pollination or honey production by honey bees in that year. For this reason, the value of pollination services provided by honey bees is not attributable to recent live animal imports. The same is true for most non-native livestock such as cattle, sheep and pigs, which were introduced centuries ago, are fully domesticated, and whose economic value therefore is not included in this analysis. Most introductions of non-native species for game (hunting and fishing) purposes also date back decades or centuries, and as such are not the subject of this analysis, although they may generate large revenues and net benefits for the related industries and participants (American Sportfishing Association, 2002; Loomis, 2005; Fish and Wildlife Service, 2003).

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[10] The ten percent estimate is based on the performance of PetsMart Inc., a major pet industry company. PetsMart has a 5-yr average operating margin of 7.5%, and a 5-yr average EBITD (earnings before interest, taxes, and depreciation) margin of 11% (Reuters, 2007).

[11] In cases where substitutes for imported live animals exist in the applications in which these animals are used, the net benefit contribution of imported live animals consists only of the increased producer surplus that stems from their (presumably) lower cost compared to alternative inputs, or from foregone revenues from lower quantities or prices of products using alternative inputs that might result from a reduced attractiveness of the product to consumers.

[12] These crops include alfalfa, almonds, apples apricots, asparagus, avocados, blueberries, brambleberries, broccoli, carrots, cauliflower, celery, cherries, citrus fruits, cotton, cranberries, cucumbers, grapes, kiwifruit, macadamia nuts, melons, nectarines, olives, onions, peaches, pears, plums, pumpkins, peanuts, soybeans, squash, strawberries, sugarbeets and sunflowers.

Recreational impacts attributable to current live animal imports are primarily those associated with animals displayed in zoos and aquaria, as well as animals used on exotic game ranches. However, estimating the economic value of imported animals in these uses would require identifying the share of revenue or profits in these industries that is attributable to imported, as opposed to domestically-bred and native, animals.

Table 2: Economic values of benefits associated with 2004 live wild animal imports

	Value and value measure	
Benefits	*Gross value*	*Net value*
Live animal imports	~$109 million/year (2000-2004 avg.) – Market price (declared wholesale value)	n/a
Pet industry	~$3.3 billion/year Market price (sales value)	~$330 million/year in profits (EBITD)
Biomedical industry	n/a, but >0	n/a, but >0
Agriculture (livestock, crop pollination + biocontrol services) and aquaculture industries	n/a, but >0	n/a, but >0
Food industry	n/a, but >0	n/a, but >0
Recreation (aquaria, zoos, game hunting & sport fishing)	n/a, but >0	n/a, but >0

Notes: n/a – not available. EBITD - earnings before interest, taxes, and depreciation.

2. Costs associated with live wild animal imports to the U.S.

Several studies have compiled estimates of the damages caused by alien-invasive species in the U.S. For example, reviewing the literature available at the time, Congress' Office of Technology Assessment (OTA, 1993) estimated that the cumulative losses caused by non-native invasive species (animals, plants and pathogens) amounted to $134 billion (2004$) during 1906-1991, or $1.6 billion per year on average. However, as the OTA pointed out, this must be considered a substantial underestimate of the actual costs, because only 14 percent of the non-native invasive species known to be harmful were included in the assessment. The estimate also did not include the costs caused by invasive human diseases, or the impact of non-native invasive species on native species diversity and ecosystem health. Furthermore, the cost estimate is biased downward because the value of losses generally is based on market values only, not on the full economic value of impacts (OTA, 1993), which comprise both market and non-market impacts.

More recent compilations of the cost the U.S. incurs from non-native invasive species have yielded far larger estimates. Pimentel et al. (2005), in their update of an earlier study (Pimentel et al., 1999), provide the perhaps most comprehensive and ambitious assessment of the economic costs associated with non-native invasive species in the U.S. Their analysis includes approximately ten times the number of species covered in the earlier OTA (1993) study, including invasive plants and human diseases. The authors estimate the aggregate cost

to the U.S. from invasive non-native species at $149 billion per year.[13] It appears that Pimentel et al. (2005) did not adjust the values they report to a particular base year. Since many of the studies from which they compile their cost estimate were conducted a decade or more prior to their 2004 compilation, their cost estimate expressed in 2004 dollars would in fact be higher than $149 billion.

As was true for the OTA (1993) study, this estimate is very rough at best. It relies in part on rather detailed information on particular impacts that have been researched in-depth; in other cases, it constructs rough estimates, sometimes employing simple extrapolations and generalizations where data are scarce (both for impacts and for the costs associated with those impacts). In many cases, it omits many of those impacts of included species for which insufficient information was not available for constructing even rough estimates. Most importantly, cost estimates in many cases only cover a few species of a genus of invasives present in the U.S. but omit many others.

Moreover, two crucial downward biases characterizing the OTA (1993) estimate also apply to Pimentel et al.'s estimate. The first is a focus on those impacts that are captured in markets, in the form of resource expenditures on prevention or management of impacts. Consequentially, both estimates capture only a share of the full range of impacts, omitting impacts on goods or services not commonly traded in markets, such as native species diversity and ecosystem health or services. The second bias stems from the use of market prices to assign economic values to the included impacts. In many cases, this leads to the underestimation of the total economic value of impacts, the correct quantification of which would require the use of valuation approaches based on willingness-to-pay (to avoid the negative impacts) or willingness-to-accept (the negative impacts) concepts. As a result, even Pimentel et al.'s figure may underestimate the actual damages associated with non-native invasive species. Nevertheless, due to the far larger number of species included in their assessment, Pimentel et al.'s (2005) study serves perhaps as the most useful starting point for estimating the costs associated with intentional legal live animal imports into the U.S.

The costs associated with intentional legal live animal imports likely constitute only a fraction of the costs caused by all alien-invasive species. For example, the costs associated with invasive plants cannot be attributed to live animal imports, except perhaps in a few rare cases where the imported animals or their transport infrastructure served as the carriers. Likewise, damages caused by arthropods, mollusks and plant microbes generally are not linked to intentional animal imports, as in most cases these species were introduced unintentionally (Pimentel et al., 2005).[14, 15] The same also is true for some other high-profile invasive animals, such as rats which were introduced unintentionally, or the brown tree snake (*Boiga irregularis*), which is thought to have been introduced to Hawaii inadvertently through cargo shipments. Pimentel et al.'s (2005) estimate also includes medical costs associated with the invasive diseases AIDS, syphilis and new influenza strains (not including

[13] Pimentel et al. give a total of $120 billion in both table 1 of their paper and their text. However, the costs listed in their table sum to $149 billion.

[14] Pimentel et al. (2005) include three mollusk species in their analysis (the Zebra mussel, the Asian clam, and the shipworm), of which only the Asian clam is suspected to have been introduced on purpose (USGS, 2001).

[15] Important exceptions do exist, however. For example, *Amblyomma* ticks enter the country with their intentionally imported reptile hosts serve as vectors for the parasite that causes heartwater disease in ruminants.

avian influenza), none of which entered the U.S. as a result of intentional legal live animal imports.

Excluding from Pimentel et al.'s estimate the costs associated with invasive plants, arthropods, unintentionally introduced mollusks and reptiles, and human diseases not attributable to live animal imports, and excluding their estimate of $5 billion of the costs of bovine spongiform encephalopathy (BSE), or mad cow disease which afflicts a domesticated species, Pimentel et al.'s study yields an estimated $55 billion per year in economic costs that are attributable to non-native invasive animals. However, some of these costs are not associated with species in an invasive state. A good example of this is human health costs from attacks by non-feral dogs.[16] Excluding the loss estimates attributable to species in a non-invasive state would lower the estimate of losses from non-native, invasive, intentionally introduced animals from $55 billion to $35 billion per year. Importantly, only a very small fraction of the impacts from these invasives are caused by current or recent introductions. Most are the result of introductions decades or even centuries ago, and this are not attributable to 2004 imports.

Conversely, this estimate based on Pimentel et al.'s analysis does not include the costs associated with recent introductions or reintroductions of diseases like Severe Acute Respiratory Syndrome (SARS), West Nile virus, exotic Newcastle disease and monkeypox that are directly, or at least potentially, linked to live animal imports. The cost estimate also does not include the costs from salmonellosis infections associated with imported reptiles, as well as a number of other exotic diseases.

In the remainder of this section, we develop estimates of the economic cost associated with these diseases.

i. Cost of diseases associated with intentional live wild animal imports

Exotic Newcastle Disease (END)

Exotic Newcastle disease (END) is classified as a foreign animal disease in the U.S. and is one of the most contagious infectious diseases of poultry worldwide (National Research Council, 2005). It affects all species of birds and generally is fatal, with death rates approaching 100 percent in unvaccinated poultry flocks and high mortality even in vaccinated birds. Due to its virulence, END causes severe economic losses when commercial poultry industries become affected. A major END outbreak in California in 1971 led to a multi-year control effort that involved the destruction of almost 12 million birds, and its eradication cost taxpayers alone over $290 million in 2004 dollars.[17] The outbreak also severely disrupted the operations of many producers, and increased the prices of poultry and poultry products for consumers (Utterback, 1973; Davidson-York et al., 1998). It took three years to fully eradicate. In 2002-2003, a major END outbreak was detected in game fowl and backyard chickens in southern California, and the following heightened END surveillance turned up further cases in Arizona, Nevada and Texas

[16] Feral cats and dogs may be considered invasives, while non-feral specimens may not. Hence, damages caused by non-feral specimens cannot be attributed to invasives.
[17] In 1971 dollars, the cost was $56 million (National Research Council, 2005).

(National Research Council, 2005). By the time the last infected bird was found, nearly 300,000 premises had been visited by inspection personnel, 22 commercial premises had been depopulated with a total of over 3.2 million birds culled, an eradication effort that involved 7,700 state and federal employees and cost federal agencies alone over $160 million (APHIS, 2004).

Although it is not possible to establish with certainty a link between live animal imports and the 2002-2003 END outbreaks in the U.S., it is reasonable to assume that poultry or wild bird imports likely were the pathway of introduction. Comparing isolates from the 2002-2003 virulent END outbreak in southern California, Nevada, Arizona and Texas to each other along with recent virulent END isolates from Mexico and Central America and reference strains, Pedersen et al. (2004) found that the U.S. isolates were most closely related those from Mexico and Central America. In particular, isolates obtained during the 2002-2003 poultry epidemic were virtually identical to isolates obtained from an infected parrot tested in a southern California pet shop in the spring of 2002, and to isolates obtained from a chicken in Mexico in 2000. An isolate from Texas obtained during 2003 appeared to represent a separate introduction of END into the United States, as this virus exhibited even closer genetic relation to the Mexico 2000 isolates than the California, Arizona and Nevada viruses. The authors conclude that the close phylogenetic relationship between the recent 2002-2003 U.S. END isolates and those viruses from countries geographically close to the United States warrants continued surveillance of commercial and noncommercial poultry for early detection of highly virulent END.

As Pedersen et al. (2004) point out, the literature contains several studies documenting that END previously had been introduced into the U.S. through the importation of exotic avian species and by water birds.

A variety of captive-bred parrot species enter the U.S. through the legal pet bird trade, generally traveling through USDA quarantine stations, and END is detected nearly every year in California, primarily in parrot and free-flying wild bird species (NRC, 2005).[18] The fact that parrots and pet birds in general frequently are implicated in the spread of this disease led the U.S. Department of Agriculture to single out imported pet birds as a major risk factor, stating that "pet birds, especially Amazon parrots from Latin America, pose a great risk of introducing exotic Newcastle into U.S. poultry flocks. Amazon parrots that are carriers of the disease but do not show symptoms are capable of shedding END virus for more than 400 days" (APHIS, 2003b). However, bird imports from other regions of the world also have been linked to END outbreaks. For example, in 2004, END entered Italy in form of a shipment of 4,000 wild parrots, lovebirds and finches from Pakistan (World Parrot Trust, 2004).

The global economic impact of END is enormous (Steneroden et al., 2004). No other poultry virus comes close and END may represent a bigger drain on the world's economy than any other animal virus. In developed countries outbreaks of END are extremely costly, and control measures, including vaccination, are a continuing loss to the industry. Even countries free of END incur high costs as they are faced with repeated testing to maintain END-free status for trade purposes. Thus, even in 2004, when there was no END outbreak

[18] In addition to legal imports of captive-bred psitticine species, wild-caught parrots are imported illegally.

in the U.S., federal and state agencies incurred costs in the form of END surveillance programs (field tests and import inspection and quarantine measures), and poultry producers incurred costs for vaccination of their flocks. Although no information is available on the aggregate magnitude of these costs in the U.S., they likely amount to well over 100 million dollars per year even in years without outbreaks. With over eight billion commercial chickens vaccinated per year against END in the U.S. (Swayne, 2002) and a minimum vaccination cost of two cents per chicken, vaccination costs alone total an estimated $164 million.[19]

SARS (Severe Acute Respiratory Syndrome)

First recognized in November of 2002 in Guangdong Province in China, the SARS virus originated in animals and is thought to have crossed into humans relatively recently (Li et al., 2006; Ren et al., 2006). Following an outbreak caused by a previously unknown coronavirus, researchers in 2003 detected the virus in Himalayan palm civets (*Paguma larvata*) and in racoon-dogs (*Nyctereutes procyonoides*) in a live animal market in Shenzen, China (Guan et al., 2003).[20] They also found that 40 percent of traders and 20 percent slaughterers of wild animals in the market were infected by the virus, but only five percent of vegetable traders. Although this does not prove that any of the infected species act as natural reservoirs of the virus in the wild, it nevertheless shows that these species, and others, act as transmitters of SARS (Guan et al., 2003).[21] In fact, the rapid increase over the past decade or so in the international trade in small wild carnivores has been suggested as a crucial contributing factor in the emergence of the SARS coronavirus (Bell et al., 2004). Wildlife markets appear to act as the main conduit for the spread of the virus across traded species. Tu et al. (2004) examined civets from different farms and a live animal market in China. They found that while civets on farms were largely free from SARS infection, around 80 percent of civets in the market contained significant levels of antibodies. They interpret their findings as suggesting that there is no widespread infection of civets on farms and that the animals rather are infected as a result of trading activities under conditions of overcrowding and species mixing. Because of the identification of palm civets as transmitters of SARS, the CDC in 2004 issued an order banning the importation into the U.S. of all civets from anywhere in the world (CDC, 2004b).

The SARS outbreaks in Asia had widespread impacts, affecting countries with even few cases, such as the United States, which registered 27 infections but no fatalities from SARS during the 2003 outbreak (GAO, 2004). Although SARS infected only 8,000 people globally, of whom fewer than a reported 800 died, the disease spread to 30 countries and its effect on the global economy totaled an estimated US$40 billion (Lee and McKibbin, 2004). SARS caused estimated losses in total marketed economic output (GDP) of countries across Asia that ranged from 0.5 to two percent, with the travel (especially airline) and tourism being the industries most heavily affected, but retail sales and foreign trade and investment also suffered impacts (GAO, 2004). Using a well-established and validated international

[19] The cost of vaccination against END ranges from two to 17 U.S. cents per chick for commercial growers, depending on vaccination method (Degefa et al., 2004; Australian Department of Primary Industries and Water, 2007).

[20] In addition, blood analysis of a Chinese ferret badger (*Melogale moschata*) from the market showed that the animal, like the civets and the raccoon-dog, had neutralizing antibodies to the virus, indicating exposure.

[21] Rather, bats recently have been identified as a natural reservoir of SARS-like coronaviruses (Ren et al., 2006; Chu et al., 2006).

economic impact simulation model, Lee and McKibbin (2004) estimate that either a temporary (six months) or a permanent SARS shock (lasting for ten years, with gradual weakening after initial shock) after the outbreak in Asia reduces total GDP in the U.S. by 0.07 percent, primarily through reduced international (business and tourist) travel to Asia and the resulting negative impacts on the service sectors associated with travel and tourism. In retrospect, the SARS shock proved to be temporary, with travel to Asia having recovered to pre-SARS levels by 2005. Thus, with U.S. GDP in 2003 estimated at $10.988 trillion (Council of Economic Advisors, 2004) and an estimated reduction in U.S. GDP in 2003-2004 by 0.07 percent, the impact of the major SARS outbreak in Asia on the U.S. is estimated a $7.8 billion (in 2004$). The simulation model upon which the SARS impact estimate is based does not only include direct impacts on affected sectors, but also incorporates linkages across sectors and within and across economies in both international trade and international capital flows. As such, it is superior to simple approaches that attempt to estimate the economic cost of SARS based on mortality and morbidity, that is, from the health-related consequences of the disease such as medical costs, lost income and reductions in human capital. Such approaches would invariable arrive at cost estimates that would appear insignificant (from a macro-level perspective), because mortality and morbidity caused by the 2003 SARS outbreak were inconsequential compared to other infectious diseases (Lee and McKibbin, 2004). However, the direct health costs constitute only a minor portion of the total economic impact of a serious and highly contagious disease like SARS.[22] Rather, the main impacts are caused by the psychological effect of fear associated with SARS, which reduces consumer demand for goods and services perceived (correctly or incorrectly) to carry an increased risk of infection.

The SARS outbreak reached Canada in 2003, and the U.S. registered eight laboratory-confirmed cases that same year. The virus most likely reached North America through people who became infected with the virus during travels abroad, although imported animals as a cause cannot be ruled out. The U.S. cost estimate from SARS presented above does not include medical costs of treatment of suspected and confirmed cases of SARS, nor does it contain costs to the U.S. health system of the 2003 SARS outbreak. For example, the U.S. Centers for Disease Control and Prevention (CDC) launched an emergency public health response in March of 2003 and established national surveillance for SARS to identify case patients in the United States and determine if domestic transmission was occurring (Schrag et al., 2004). As argued above, these costs likely are minor compared to the impact from reduced demand for goods and services.

These estimated costs of $7.8 billion SARS imposed on the U.S. can however not be attributed to live animal imports. Rather, they represent economic consequences of the outbreaks abroad. The costs from SARS that potentially are attributable to live animal imports are those associated with the U.S. SARS cases. These costs include emergency surveillance and medical measures, involving large sections of the health provider system and federal agencies. Unfortunately, no estimate of the magnitude of those costs is available.

[22] Nevertheless, as Lee and McKibbin point out, private and public medical costs of SARS could increase sharply in the future should the disease become endemic.

Highly Pathogenic Avian Influenza

Avian influenza is an infectious disease of birds caused by type A strains of the influenza virus. A highly pathogenic influenza strain was first identified in Italy in 1878. Originally, the highly pathogenic forms were only confirmed in poultry, while wild birds were thought to carry or directly spread only the mild strains.[23] However, recent evidence suggests that at least some wild waterfowl and birds imported as exotic pets carry the H5N1 virus in its highly pathogenic form (FAO, 2006; Van Borm et al., 2005; MacKenzie, 2005). Apart from being highly contagious among poultry, avian influenza viruses are readily transmitted from farm to farm by the movement of infected live birds, people (especially through contaminated shoes and clothing), contaminated vehicles, equipment, feed and cages. The highly pathogenic virus can survive for long periods in the environment. This makes it much more difficult to control the spread of the virus compared to viruses that can only be transmitted though direct contact with infected animals or their feces, as appears to be the case for example for SARS. The outbreaks of highly pathogenic H5N1 avian influenza that began in south-east Asia in mid-2003 and have now spread to parts of the Near East, Europe, Africa and North America are the largest and most severe on record. To date, ten Asian countries have reported outbreaks (listed in order of reporting): the Republic of Korea, Viet Nam, Japan, Thailand, Cambodia, the Lao People's Democratic Republic, Indonesia, China, Malaysia and Azerbaijan. Of these, Japan, the Republic of Korea and Malaysia have controlled their outbreaks and are now considered free of the disease. Elsewhere in Asia, the virus has become endemic in several of the initially affected countries. It has since spread beyond South-East Asia, and by now also has been confirmed in Russia, in Europe (Austria, Bulgaria, Croatia, Denmark, Germany, Greece, Hungary, Italy, Romania, Sweden, the U.K. and Ukraine), in Africa (Egypt, Djibouti and Nigeria), and in the Near East (Iraq and Turkey) (WHO, 2007b).

Influenza viruses are normally highly species-specific, meaning that viruses that infect an individual species (humans, certain species of birds, pigs, horses and seals) stay "true" to that species, and only rarely spill over to cause infection in other species. Since 1959, instances of human infection with an avian influenza virus have been documented on only ten occasions. Of the hundreds of strains of avian influenza A viruses, only five are known to have caused human infections: H5N1, H7N2, H7N3, H7N7 and H9N2. In general, human infection with these viruses has resulted in mild symptoms and very little severe illness, with one notable exception: the highly pathogenic strain of the H5N1 virus (there also exists a low pathogenic H5N1 strain). Of all influenza viruses that circulate in birds, the H5N1 virus is of greatest present concern for human health for two main reasons. First, the H5N1 virus has caused by far the greatest number of human cases of very severe disease and the greatest number of deaths. Since 2003, it has infected 291 people, 172 (59 percent) of which died as a result of the infection (WHO, 2007a). It has crossed the species barrier to infect humans on at least three occasions in recent years: in Hong Kong in 1997 (18 cases with six deaths) and 2003 (two cases with one death), and in the current outbreaks that began in December 2003 and were first recognized in January 2004, with human infections in Thailand and Vietnam, in 2004, Cambodia, China, Indonesia, Thailand and Vietnam in 2005, in Azerbaijan, Cambodia, China, Djibouti, Egypt, Indonesia, Iraq, Thailand and Turkey in 2006, and in

[23] All highly pathogenic strains of the avian influenza so far have been of the H5 and H7 subtypes, though other strains have the potential to become highly pathogenic through mutations.

Cambodia, China, Egypt, Indonesia, Lao People's Democratic Republic and Nigeria so far in 2007 (WHO, 2007a).[24]

A second implication for human health, of far greater concern, is the risk that the H5N1 virus – if given enough opportunities – will develop the characteristics it needs to start another influenza pandemic. The virus has met all prerequisites for the start of a pandemic save one: an ability to spread efficiently and sustainably among humans. Although often difficult to determine with certainty, a number of recent incidences have been reported of suspected human-to-human transmissions, mostly among close family members (The Writing Committee of the World Health Organization [WHO] Consultation on Human Influenza A/H5, 2005). Though so far instances of human-to-human transmission of the H5N1 virus have been rare, limited and not sustained, and no evidence has been found of a genetic reassortment between human and avian influenza A virus genes that could lead to mutations conducive to a pandemic, the H5N1 epizootic continues to pose an important public health threat. Moreover, while H5N1 is presently the virus of greatest concern, the possibility that other avian influenza viruses known to infect humans might cause a pandemic cannot be ruled out.[25]

Between 1997 and 2005, there have been 16 documented outbreaks of low pathogenic avian influenza A viruses (H5 and H7) in the U.S. There also was one outbreak of highly pathogenic (H5N2) influenza in poultry during this period, which did not involve transmission to humans (CDC, 2006b).[26] The latter outbreak occurred on a chicken farm in Texas but was quickly eradicated thanks to a concerted control effort by the private sector and federal, state and local authorities (CDC, 2006b). There is no evidence that highly pathogenic avian influenza currently exists in the United States. However, recent outbreaks in Canada (2004, type H7N3, with transmission to humans) and Mexico (2006, type H5N2, without transmission to humans) highlight the presence of the threat. There have been two prior outbreaks of highly pathogenic avian influenza in poultry in the U.S. in 1924 (H7) and 1983 (H5N2), neither of which resulted in significant human illness (USDA, 2007). The 1983-84 outbreak, which was eradicated in 1986, resulted in the destruction of approximately 17 million chickens, turkeys and guinea fowl in the northeastern United States to contain and eradicate the disease, at a cost of more than $70 million (Jacob et al., 1998), or $130 million in 2004$. In 2002, an outbreak of low pathogenic avian influenza in the eastern U.S. led to the destruction of 4.7 million chicken and turkeys (Tumpey et al., 2004). The 2004 outbreaks of low pathogenic H5N2 in a chicken farm in Texas and in live-bird markets in Houston supplied by the farm, and of H7N2 in two chicken farms in Delaware and live-bird markets

[24] Human infections with another highly pathogenic influenza A strain, H7N3, also occurred in Canada in 2004 (CDC, 2006a). In addition, low pathogenic H5N1 infections have been documented in a number of additional countries (WHO, 2007c).

[25] The foregoing paragraphs draw heavily on the following sources: World Health Organization (WHO) (2006), Avian influenza ("bird flu") - Fact sheet, [online] *http://www.who.int/mediacentre/factsheets/avian_influenza/en/*, February 2006, last accessed May 3, 2007; Centers for Disease Control and Prevention (2006), Avian influenza infections in humans, [online] *http://www.cdc.gov/flu/avian/gen-info/avian-flu-humans.htm*, last modified August 2006, last accessed May 3, 2007; Centers for Disease Control and Prevention (2006), Past avian influenza outbreaks, [online] *http://www.cdc.gov/flu/avian/outbreaks/pdf/past.pdf*, February 17, 2006, last accessed May 3, 2007.

[26] Transmission of low pathogenic avian influenza to humans did occur in a 2003 event in New York, involving the H7N2 virus (CDC, 2006b).

in New Jersey supplied by the Delaware farms, as well as farms in Maryland, led to the destruction of all poultry involved.[27]

Avian influenza A outbreaks of subtypes H5 or H7 (both low or highly pathogenic varieties) in a country constitute notifiable events under OIE (World Organization for Animal Health, by its French initials) rules (Moore and Morgan, 2006). Outbreaks in a country trigger import bans on poultry products by most countries importing poultry from the affected country (ibid.). After the 2004 outbreaks in Texas, Delaware and New Jersey, the European Union and twelve other countries banned all U.S. poultry shipments, while 15 other countries have banned poultry from the affected states. Complete bans by the People's Republic of China, Hong Kong and South Korea remained in effect for most of 2004 and resulted in a three percent decrease in total U.S. poultry exports for that year (Moore and Morgan, 2006).[28] Some countries initially imposed complete bans but later restricted them to imports from only selected U.S. states or counties. Although most bans were rescinded, a few remained in effect at least through September 2006 (Moore and Morgan, 2006; USDA Foreign Agricultural Service, 2006).

With U.S. poultry exports valued at about $2.2 billion (15 percent of its chicken production) in 2004 (Moore and Morgan, 2006), the three percent drop in poultry exports that resulted from the 2004 outbreaks represented a $69 million (2004$) loss of export revenues in 2004 alone. Given that most poultry cuts used for export are not popular in the U.S., reductions in exports do not translate into increased domestic poultry supplies (Purdum, 2004). Such a shift from export to domestic consumption could potentially reduce lost export revenues. On the other hand, the downward pressure on domestic poultry prices from increased domestic supplies would tend to lower producer revenues. It is therefore not clear if lost export revenues could be made up by increased volume of domestic sales, even if consumers demanded the cuts formerly destined for export. The impact of avian influenza outbreaks and associated export and market impacts extends beyond the poultry sector, to feed and other input sectors (Moore and Morgan, 2006).

Given the lack of evidence tying the recent outbreaks of avian influenza in the U.S. to intentional live wild animal imports, the costs associated with these outbreaks cannot with certainty be attributed to live animal imports. Not all impacts associated with avian influenza can be ascribed to live bird imports, as avian influenza may also enter a country through migrating wild birds. As the U.N. Food and Agriculture Organization (FAO, 2006, p. 7) points out in a recent assessment, although isolations of highly pathogenic avian influenza H5N1 virus from migratory waterfowl in many countries in Asia and Europe suggest that these birds could play a role in virus introduction, "other factors such as legal or illegal trade of birds and poultry greatly contribute to disease spread within and across regions." Another recent analysis (Gauthier-Clerc et al., 2007) examined the arguments both for and against the role of migratory birds in the global dispersal of highly pathogenic avian influenza H5N1 and concluded that, while wild birds undoubtedly contribute to the local spread of the virus in the wild, human commercial activities, in particular those associated with poultry, are the major factors that have determined its global dispersal.

[27] In Texas, 7,000 chickens were destroyed; in Delaware, 84,000 (CDC, 2006b; Purdum, 2004).

[28] These three countries, plus Japan, accounted for 22 percent of U.S. broiler exports in the period from 2001 to 2003 (Moore and Morgan, 2006).

The importance of the link between wildlife trade and avian influenza has been confirmed through a number of documented cases where the virus entered a country through live bird imports. For example, in 2005, highly pathogenic H5N1 type A influenza was isolated from mountain hawk eagles illegally imported to Belgium from Thailand (Van Borm et al., 2005). In October of the same year, the same highly pathogenic strain was discovered in a parrot imported to the U.K. from Surinam that died in quarantine of H5N1, probably infected by wild birds from Taiwan also held at the facility (MacKenzie, 2005).

West Nile Virus

West Nile (WN) virus is transmitted by mosquitoes among birds and other vertebrates. Until its recent introduction to the Western Hemisphere, its geographic distribution ranged from Africa, to the Middle East, western and central Asia, India, Australia and Europe. Recent studies suggest that the virus now has become established in the U.S. following its introduction into the country in 1999. The first recorded epidemic occurred in Israel in the early 1950s. More recently, outbreaks of encephalitis in humans caused by WN virus have been documented in Romania and Russia (Anderson et al., 2001). Following its introduction to the northeastern U.S., WN virus caused the deaths of seven humans among 62 confirmed cases in New York City and nearby counties in late summer 1999. Newcomb (2003) estimates that the costs for treatment and containment of the WN virus outbreak in 1999 amounted to $500 million.

It is not clear whether or not the WN virus was introduced into the U.S. through legal live animal imports, as several other possible pathways exist. For example, the virus could have been introduced by migrating birds, through illegal imports of infected live birds, by infected humans, or through human-transported mosquito vectors (Anderson et al., 2001). However, because it first appeared in a major international gateway, commerce may have played a role (Petersen and Marfin, 2002). The WN virus that caused the first recorded outbreak of WN in the U.S. in 1999 was traced back to an infected Chilean flamingo in the New York Zoological Garden and was most closely linked to a WN virus found in a dead goose in Israel in 1998 (Lanciotti et al., 1999). In addition, many imported non-native birds also serve as vectors or reservoirs of West Nile virus in the U.S. (CDC, 2007c).[29]

Since its emergence in the U.S. until 2006, there have been a total of nearly 24,000 recorded human cases, 962 of which were fatal (CDC, 2007a). No estimate exists of the economic cost of the morbidity (treatment cost, suffering and lost productivity) and mortality associated with WN virus. Estimation of these costs is beyond the scope of this paper. Nevertheless, a rough assessment suggests that the economic loss associated with WN virus in the U.S. was on the order of hundreds of millions of dollars in 2004. With 100 fatalities from WN virus in 2004 (CDC, 2007a) and using a conservative average value of a statistical life of $4 million, the total estimated economic loss from premature mortality caused by WN virus would be estimated at $400 million in 2004.[30]

[29] According to the CDC's West Nile Virus avian mortality database, 60 of the 317 bird species for which fatalities from WNV have been reported are non-native (CDC, 2007c).

[30] The value of a statistical life (VSL) approach assigns a dollar value to premature mortality based on forgone earnings. The average value of a statistical life in the U.S. ranges from $1.7-$2.0 million to almost $10 million, depending on the estimation methodology used and the age of the affected individual (Aldy and Viscusi, 2006).

The WN virus also causes high fatality rates in some wild bird populations and in horses. In 2002, a total of 8,063 equine WN virus cases were reported, of which approximately one-third were fatal (APHIS, 2003a).

In addition to these costs associated with the impacts of the disease on human and animal populations, WN virus also imposes substantial resource costs on federal, state and local institutions for blood screening, community surveillance, and monitoring and interventions. For example, APHIS implements WN virus surveillance and emergency response (APHIS, 2003a), the costs of which are already included in Table 6. The Centers for Disease Control and Prevention (CDC) in FY 2004 spent $38 million on WN virus activities (CDC, 2004a).[31]

Monkeypox

Monkeypox is a rare viral disease occurring primarily in central and western Africa. In infected humans the disease causes a rash, fever, headache, muscle aches, backache, swollen lymph nodes, a general feeling of discomfort and exhaustion. The illness typically lasts for two to four weeks. In Africa, monkeypox is fatal in as many as ten percent of human cases (CDC, 2003a). Monkeypox was introduced to native rodents in the U.S. by wild African rodents imported for the pet trade in April 2003 (Guarner et al., 2004). These rodents passed on the virus to prairie dogs housed in the same pet store, which then passed it on to exotic pet dealers, pet owners and veterinary care workers in the U.S., with the first cluster of human monkeypox cases reported in May and June of that year (Guarner et al., 2004).[32] Overall, 72 individuals were documented to have contracted the infection. None of the cases were fatal. However, research showed that this was due to the fact that the virus involved was the West African biological strain, which is much less virulent than the strain found in the Congo basin (Chen et al., 2005). Following the 2003 outbreak, the CDC and FDA issued an order prohibiting the import of all African rodents irrespective of their origin. This order still is in effect (CDC, 2006c), and no cases of monkeypox have been reported in the U.S. since the 2003 outbreak. No estimates are available of the costs associated with the 2003 outbreak in the U.S.

Reptile-associated salmonellosis

A high proportion of reptiles are asymptomatic carriers of *Salmonella* bacteria, with fecal carriage rates that can exceed 90 percent. Attempts to eliminate *Salmonella* carriage in reptiles with antibiotics have been unsuccessful and have led to increased antibiotic resistance. A wide variety of Salmonella serotypes has been isolated from reptiles, including many that rarely are isolated from other animals. *Salmonella* infections usually cause gastroenteritis (with diarrhea, fever and abdominal cramps) lasting for four to seven days, but in severe cases salmonellosis can result in invasive illness such as septicemia and meningitis, especially in infants and immuno-compromised persons (CDC, 2003b). In these cases, the infection is spreading from the intestines to the blood stream and to other body sites and can cause death unless the person is treated promptly with antibiotics. Each year around 1.4 million persons in the U.S. develop salmonellosis, of whom around 15,000 are hospitalized and

[31] By FY 2006, this amount had increased to $45 million (CDC, 2007b).

[32] The virus was confirmed in one Gambian rat (*Cricetomys* spp.), two rope squirrels (*Funiscuirus* spp.), and three dormice (*Graphiurus* spp.) in a shipment from Ghana.

around 400 die from acute infections (Voetsch et al., 2004). Reptile- and amphibian-associated salmonellosis poses a significant risk to infants and young children (Milstone et al., 2006). Reptile-associated salmonellosis infections are more likely to be associated with invasive disease (Cieslak et al., 1994) and more commonly lead to hospitalization (Ackman et al., 1995).

Every year, imported reptiles cause thousands of cases of *Salmonella* infection in the U.S. A recent study (Mermin et al., 2004) estimated that in 1997, six percent of all sporadic *Salmonella* infections were attributable to reptiles, with the reptile-attributable share rising to eleven percent of all cases for persons under 21 years old. Based on these findings, contact with reptiles was the cause of an estimated 74,000 reptile-related cases of *Salmonella* infections in 1997. Since then, this number is likely to have increased sharply, in tandem with rising pet reptile ownership, which increased from an estimated 7.3 million in 1997 to an estimated 13.4 million in 2007.[33] Although the estimated number of annual *Salmonella* cases in the U.S. not related to outbreaks has remained about the same since 1997, the large increase in the number of pet reptiles suggests that the share of all reptile-associated *Salmonella* infections in 2004 was higher than in 1997.[34]

Applying Mermin et al.'s (2004) findings of a six percent share of reptile-associated salmonellosis cases among all 1997 salmonellosis cases to the estimated 1.19 million not outbreak-related salmonellosis infections that occurred in 2004 (see fn. 34) yields a total of almost 72,000 reptile-associated *Salmonella* infections in 2004. However, this is likely to be a lower-bound estimate. Given that the number of pet reptiles in U.S. households increased by about 40 percent during 1997-2004, it would be expected that the share of reptile-associated salmonellosis cases also increased. Assuming a constant relation between the number of pet reptiles and reptile-associated salmonellosis cases, the total number of such cases would be expected to be around 40 percent higher, or approximately 98,000.

Not all pet reptiles in U.S. households are imported. No published estimate is available of the share of imported pet reptiles among all pet reptiles in the country. However, the recent trend toward owning imported reptiles, especially iguanas and snakes, has resulted in increasing reports of reptile-associated salmonellosis cases in the U.S. (Wisconsin Division of Public Health, 2004). Over 1.8 million reptiles were imported on average per year during 2000-2004 (Defenders of Wildlife, 2007). With the number of reptiles held in U.S. households around 10 million in 2004, and assuming an average life expectancy of one year for imported reptiles, imported reptiles accounted for an estimated 18 percent of all pet

[33] Based on data obtained from the American Pet Products Manufacturers Association's biannual national pet owners surveys.

[34] In 1997, the total number of *Salmonella* cases in the U.S. was an estimated 1.41 million (Mead et al., 1999), of which an estimated 88 percent, or 1.24 million, were not related to outbreaks (Mermin et al., 2004). The total number of cases is estimated to be 38 times the number of reported cases (Mead et al., 1999), based on FoodNet data and the "sequential surveillance artifact" multiplier derived by Chalker and Blaser (1988). In 2004, the total number of reported *Salmonella* cases was 35,661 (Centers for Disease Control and Prevention, 2005), which, using the multiplier of 38, yields an estimated total of 1.36 million *Salmonella* infections for that year, of which an estimated 1.19 million were not related to outbreaks. This represents a four percent decrease over 1997.

reptiles in the U.S. in 2004.[35] Depending on whether the low estimate of 72,000 reptile-associated salmonellosis cases is used or the higher estimate of 98,000, an estimated 13,000-18,000 salmonellosis cases were attributable to imported reptiles in 2004. Further assuming conservatively that cases of reptile-associated *Salmonella* infections are characterized by a similar likelihood of hospitalization and death as *Salmonella* infections in general, imported reptiles are estimated to have caused around 160-220 hospitalizations and between five and seven deaths in 2007 (Table 3). These estimates are conservative – Cieslak et al. (1994) found that reptile-associated *Salmonella* serotypes in fact are associated with higher hospitalization rates than overall *Salmonella* cases.

Table 3: Estimated numbers of different health outcomes caused by *Salmonella* infections associated with imported reptiles, 2004

Health endpoint	*Low estimate*	*High estimate*
Cases	13,018	17,833
Hospitalizations	157	215
Deaths	5	7

Notes: Hospitalization and death rates based on Mead et al. (1999).

To derive estimates of the costs associated with the health impacts caused by imported reptiles, we multiply the number of reptile-associated salmonellosis cases with the Economic Research Service's (ERS) base cost estimates for *Salmonella* infections (Table 4). The ERS's base costs shown in Table 4 are based on the Cost-of-Illness (COI) approach, which includes only losses associated with marketed goods and services, such as lost productivity or income and medical costs from physician visits and hospitalization. The ERS estimates actually omit part of the COI as they do not include any medication costs. More importantly, the ERS base cost estimates also omit the disutility associated with pain and suffering, inconvenience, and forgone engagement in non-work activities during illness.

Table 4: ERS estimates of cost of Salmonella infections by severity

Health endpoint	*Estimated average cost per case (2004$)*	*Cost categories*	
		included	*omitted*
Infection – no physician visit	46	Lost productivity [1]	*
Infection – physician visit	453	Lost productivity [1], medical expenses	*
Hospitalization	8,823	Lost productivity [1], medical expenses	*
Death	4,942,127	Lost productivity [2], medical expenses, forgone income	*

Notes: [1] Applied only to employed cases (44.5 percent of all cases). [2] Applied only to employed cases (50.2 percent of all cases). * Pain and suffering, inconvenience, time lost from non-work activities.
Source: ERS (2007).

[35] An estimated 50-90 percent of reptiles die in the first year of captivity, in addition to the 10-50 percent that die during importation and shipment (San Diego Natural History Museum, 2007).

The value of those omitted losses can be estimated using stated preference approaches that ask individuals directly how much they would be willing to pay to avoid various health impacts. Compared to the COI method, the Willingness-to-pay (WTP) approach more closely approximates actual societal costs because it uses the value individuals place on obtaining the benefits of avoiding specific negative health outcomes (Freeman, 2003). By including more than just market costs, cost estimates of *Salmonella* infections using WTP approaches are, not surprisingly, higher than COI-based estimates.

For example, the Foodborne Illness Risk Ranking Model, or FIRRM (Batz et al., 2004; Resources for the Future, University of Maryland, and Food Safety Research Consortium, 2004) allows the use of WTP-based cost estimates for estimating the cost of infections (with or without physician visit) and hospitalizations from *Salmonella* infections. As a result, the costs associated with non-lethal *Salmonella* infections more than double in the FIRRM compared to the cost estimate based on the ERS's COI values. The ERS cost calculator specifically recognizes the incompleteness of COI-based cost estimates of *Salmonella* and provides the option to select FDA estimates of the value of the disutility associated with pain and suffering, inconvenience, and lost non-work activity time resulting from *Salmonella*-associated infections.[36]

Nevertheless, in the interest of constructing conservative estimates of the cost of salmonellosis associated with imported reptiles, we employ the ERS's COI values (Table 4) in our estimates. Applying these case-specific cost estimates to the total number of *Salmonella* cases attributed to imported reptiles, it becomes obvious that the total cost of the health impacts from imported reptiles is substantial. As Table 5 shows, the medical, productivity and income losses alone amounted to between $29 million and $39 million in 2004.

Table 5: Estimated costs from health effects caused by *Salmonella* infections associated with imported reptiles, 2004

Health endpoint	*Low estimate (2004$)*	*High estimate (2004$)*
Infection – no physician visit	575,613	788,511
Infection – physician visit [a]	155,192	212,592
Hospitalization	1,385,492	1,897,935
Death	26,630,796	36,480,543
Total	28,747,094	39,379,581

Notes: Based on Tables 3 and 4. [a] Physician visits are documented *S.* cases – 2.6 percent of all cases (Mead et al., 1999).

Public agency costs

Public agencies at federal, state and local levels incur expenditures for a range of activities aimed at the prevention, detection and control of diseases and pests associated with imported animals. For example, USDA's Animal and Plant Health Inspection Service

[36] The FDA uses values of $800 for a *Salmonella* case not involving physician visits, $1,900 for a case involving physician visits, and $7,800 for a case involving hospitalization (all average values, 2004$) (FDA, 1998; ERS, 2007).

(APHIS) in 2004 spent a total of one quarter of a billion dollars on programs related to diseases and pests associated with live wild animal imports (Table 6), including surveillance for END and other diseases and pests. Not all of the listed activities are associated exclusively with intentional live animal imports. Nevertheless, these $248 million, representing approximately one quarter of APHIS's total 2004 expenditures of $1.09 billion, provide an upper-bound estimate of the resources APHIS alone spends on activities that predominantly are related to live animal imports. They do not include costs incurred by other federal agencies or by local and state authorities for invasives-related surveillance and control activities.

Table 6: Cost of Animal and Plant Health Inspection Service (APHIS) program activities related to diseases and pests associated with live animal imports, 2004

Activity	*2004 Expenditures, million $*
Agricultural quarantine inspection (AQI) [a]	25
All other pest and disease exclusion	58
Animal health monitoring and surveillance	95
Emergency management system	10
Pest detection	24
All other pest and disease management [b]	36
Total	248

[a] Appropriations only – does not include user fees. [b] Does not include boll weevil, Brucellosis eradication, Chronic Wasting disease, Low Pathogen Avian Influenza, Pseudorabies, Scrapie, Tuberculosis and Wildlife Services operations.
Source: USDA (2006).

Table 7 presents a summary of the cost estimates compiled in this section. Some of the diseases and associated costs either are conclusively linked to live animal imports, or such imports are considered the most likely cause of the outbreaks of the diseases in 2003-04, or of the chronic occurrence of the disease (in the case of reptile-associated salmonellosis). Other disease outbreaks in 2003-04, such as those caused by SARS, avian influenza, or West Nile virus, are not conclusively linked to live animal imports as they may have entered the country through other pathways. For some of the diseases, no information is available on the estimated economic damages attributable to live animal imports, although in some cases, these costs likely were substantial. The table also presents an estimate of the damages caused by intentionally-imported non-native invasive species, based on Pimentel et al.'s (2005) study. Although these costs are attributable to imported species, they are for the most part not attributable to imports considered in the time period covered in the present study (2003-2004).

Though the diseases discussed in this part currently are those causing the most serious impacts, they are not the only ones that are imported through live animals. Others include heartwater disease, malignant catarrhal fever, chytridiomycosis and the ranavirus (Defenders of Wildlife, 2007).

Table 7: Partial estimate of costs definitively or potentially caused by intentional live wild animal imports into the U.S., 2004

Type of cost	*Cost per year (2004$)*
Pimentel et al. (2005) – costs associated with intentional live wild animal imports	[$35 billion] [a]
Costs not covered in Pimentel et al.'s estimate:	
Costs caused by diseases	
SARS *	n/a
AI *	$66 million [b]
END	$160 million
WNV *	$438 million [c]
Monkeypox	n/a
Salmonellosis (reptile associated only)	$29-39 million [e]
APHIS activities related to live wild animal imports	$204 million [d]
Costs caused by invasive animals	
Control (surveillance, containment, eradication)	n/a
Conservation efforts for T&E species	n/a
Resource damages from invasives	n/a

Notes: n/a – not available. [a] A dominant portion of the estimated costs is not attributable to recent introductions, but rather to introductions during prior decades or even centuries. *Potentially caused by live animal imports. Intentional legal live animal imports have not been established conclusively as the pathway for entry of the disease into the U.S. [b] Surveillance and quarantine costs are accounted for under APHIS's expenditures. [c] Includes cost of premature human mortality from WN virus and CDC expenditures on WN virus activities. Does not include costs of equine mortality or wild bird fatalities. [d] Based on Table 6; excludes the cost of APHIS' BSE surveillance activities ($44 million). [e] Costs associated with cases not involving physician visits, cases involving physician visits, hospitalizations and deaths; includes cost of market impacts only (i.e., excludes lost utility associated with pain and suffering, inconvenience and time lost from non-work activities). See text for more information on cost estimates.

ii. Costs of invasive species associated with intentional live wild animal imports

In addition to being the cause of introduced human and animal pathogens and diseases, legal intentional, live wild animal imports also constitute a pathway through which invasive species enter domestic ecosystems. In some cases, the generally illegal release of these animals occurs intentionally; in others, it is the result of accidental escape of animals from confinement. Intentional release was the presumed cause for invasions by the snakehead (*Channa* spp. and *Parachanna* spp.), the Asian clam (*Corbicula fluminea*), the Burmese python (*Python molurus bivittatus*), the common boa (*Boa constrictor*), the Indian mongoose (*Herpestes auropunctatus*), the Nile monitor (*Varanus niloticus*), the Nutria (*Myocastor coypus*) and the Rhesus monkey (*Macaca mulatta*), to name but a few high-profile species (Pimentel et al., 2005; Florida Fish and Wildlife Conservation Commission, 2007). In addition, presumed unintentional releases cause many non-natives species to escape into local ecosystems, for example through the aquarium trade (Semmens et al., 2004; Padilla and Williams, 2004).

Invasion of local ecosystems by imported species is a major concern because non-native invasive species constitute one of the most important threats to biodiversity, both globally (Macdonald et al., 1989; McNeely, 2001; IUCN Invasive Species Specialist Group, 2000; Baillie et al., 2004) and in the U.S. (Wilcove et al., 1998; Light and Marchetti, 2007). All

species listed in the preceding paragraph except the Rhesus monkey have been identified as a treat or potential threat for the survival of threatened or endangered native species, through predation, food competition, or habitat alteration (Pimentel et al., 2005; Florida Fish and Wildlife Conservation Commission, 2007).

To the extent that invasions associated with imported animals are an important cause of species endangerment, conservation efforts for the affected native species must in part be attributed to the import of the alien-invasive species contributing to the endangerment.

Quantification of the economic damages caused by biodiversity losses is difficult. Incomplete knowledge of the range and magnitude of ecosystem functions performed by particular species and of the relative importance of these functions to the maintenance of ecosystem health often prevents the quantification of the value of the ecosystem services directly or indirectly provided by a species (Vatn and Bromley, 1995).

Revealed and stated preference approaches commonly used in economics to assign value to goods and services in many cases cannot be relied upon to reveal the full economic value of particular species or ecosystems. The reasons for this are the presence of externalities, which distorts market prices;[37] our limited quantitative understanding of the functional relationships among the myriad structural components of ecosystems, and constraints in individuals' ability to assign value to particular ecosystem functions or services (Vatn and Bromley, 1995). As a result, neither revealed nor stated preference approaches can be relied upon to adequately capture the full economic value of particular species or ecosystems. Nevertheless, a lower-bound estimate of the economic value of an individual species may be derived by quantifying the values of particular use they provide, including direct uses such as recreation (e.g., wildlife viewing, hunting, fishing), indirect uses such as particular ecosystem services (e.g., biological pest control) and passive uses (existence values), recognizing that these constitute only part of the full value of a species (Gowdy, 1997).

Costs of conservation efforts associated with species endangerment are easier to quantify, at least in principle. These costs comprise all resources expended to prevent or reduce threats to the survival of a species. They include costs private and public entities incur from recovery efforts associated with the listing and designation of critical habitat for species, and the design and implementation of habitat conservation plans and species recovery plans. They also include conservation actions taken to prevent native species from reaching threatened or endangered status. Much of this information is available, if in a very dispersed form, at federal and state resource agencies. Compilation of these cost estimates is beyond the scope of this paper. However, the U.S. Fish and Wildlife Service's (FWS) economic impact analyses of critical habitat designation alone (i.e., not including habitat conservation plans, species recovery plans, or state, local and private efforts) put the cost of species protection in the U.S. at hundreds of millions of dollars per year for species primarily at danger from invasives.[38, 39] To the extent that invasive imported animals are a contributing

[37] It is by now well-recognized that market prices often fail to correctly indicate the relative scarcity of natural resources (Norgaard, 1990).

[38] FWS economic impact analyses generally do not distinguish costs associated with critical habitat designation from those associated with listing of a species. For the purpose of this analysis, this does not constitute a problem, as both listing and designation of critical habitat are the result of species endangerment.

factor in the endangerment of these native species, they can be assigned a share of the cost of these conservation efforts. Such cost apportionment could be based on expert assessment of their relative contribution to endangerment.

In addition to negatively impacting native biodiversity, invasive species also cause direct economic harm by impacting production infrastructure or resource productivity. For example, nutria damage water-retention and flood control levees, reservoir dams and irrigation ditches (APHIS 2005b; Bounds, 2000), increasing agricultural production costs or lowering land productivity; the common carp (*Cyprinus carpio*) degrades shallow lakes by causing excessive turbidity, which can lead to declines in waterfowl and important native fish species (Gulf States Marine Fisheries Commission, 2007) with associated reductions in the recreational value of ecosystems; the Asian carp (various species) can disrupt local food chains and displace native competitors, with negative impacts on recreational fisheries (EPA, 2006; Conover et al., 2006). The negative economic impacts associated with these invasives can be substantial, although no aggregate estimates have been compiled. In addition to impacts on resource productivity, invasive animals also require control efforts (e.g., nutria eradication campaigns and carp control plans) costing millions of dollars per year.[40] Overall, federal agency expenditures on invasives totaled nearly $1.1 billion in FY 2004 (National Invasive Species Council, 2005). However, this amount covers all invasives, not just intentionally imported live animals.

However, as in the case of the benefits associated with imported animals, a large share of the costs associated with biodiversity loss, conservation efforts and resource damages cannot be attributed to present imports, as many invasions and resulting damages are the outcome of species imports decades ago. Nevertheless, they serve as an example of the potential costs that can be associated with future invasions resulting from present or future imports.

iii. Total costs associated with live wild animal imports, 2004

Given the gaps in existing data on the impacts caused by intentionally imported live wild animals and the challenges associated with closing these gaps, it is not possible for this particular study to derive comprehensive estimates of the size of these costs. Nevertheless, available data show that live wild animal imports cause substantial economic damages in the U.S.

The size of damage estimates is very sensitive to the temporal boundaries set by the analysis. In this part, we compiled estimates for the year 2004 of the damages considered to be linked directly to intentional current live wild animal imports, at least for the limited number of

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[39] For example, the costs of activities associated with listing and critical habitat designation for the Bull trout (*Salvelinus confluentus*) alone are estimated at over $60 million per year (Northwest Economic Associates, 2005; Bioeconomics, Inc., 2004). Like the Chinook Salmon (*Oncorhynchus tshawytscha*) and the Cutthroat trout (*Salmo Clarki*), the Bull trout is primarily at risk from imported invasive fish like Brook trout (*Salvelinus fontinalis*), Rainbow trout (*Oncorhynchus mykiss*), or Brown trout (*Salmo trutta*).

[40] For example, the nutria eradication programs in Maryland and Louisiana alone received appropriations of $6 million in total for each of fiscal years 2004-2008 (U.S. Congress, 2003). Installation of a dispersal barrier to control Asian carp on the Chicago Sanitary and Ship Canal in Illinois cost $2.2 million, with upgrades for continued operation and improved effectiveness of the barrier costing an additional $5.5 million; a second barrier is being completed and will have estimated operation costs of $450,000 per year (Conover et al., 2006).

diseases included in our analysis. These damages, associated with END and reptile-associated salmonellosis, plus expenditures by some of the federal agencies involved in their control, amounted to an estimated $400 million in 2004 alone (Table 8).

Table 8: Low and high estimates of costs of diseases and damages to the U.S. associated with imported live wild animals, 2004

	Low cost estimate (2004$)	*High cost estimate (2004$)*
Costs of diseases either *potentially or definitively* linked to 2003-04 live wild animal imports *	901 million	911 million
Costs only of diseases considered *definitively* linked to 2003-04 live wild animal imports *	397 million	407 million
Costs of damages caused by imported live wild animals *regardless of time of importation*: **	[35 billion]	

Notes: *Cost of diseases includes only those diseases for which cost estimates were compiled in this study. **Includes estimated $35 billion of damages associated with intentionally imported invasive animals, based on modification of Pimentel et al.'s (2005) estimates as discussed in text. Note that likely almost all of these costs are attributable to imports in prior years.
Source: Table 7

If damages potentially caused by current live wild animal imports are included, the damage estimate increases to approximately $900 million in 2004. The higher costs comprise the estimated damages from Avian Influenza and West Nile Virus. Some or all of these diseases might have been introduced into the U.S. by pathways other than live animal imports. For example, both avian influenza and West Nile virus might have been introduced by wild birds.

Both the low ($400 million) and the high ($900 million) end of these two sets of estimates only capture costs related to animal-borne diseases. They do not capture infrastructure or resource damages caused by imported animals. It is impossible to estimate how much of the total infrastructure and resource damages caused in 2004 by all ever intentionally imported species were caused by current (2003-04) species imports. Based on Pimentel et al.'s (2005) study, we estimate that the damages caused by intentionally introduced invasives were around $35 billion in 2004. However, these damages were caused by all intentionally introduced non-native invasives included in those authors' study, not only by the recently imported specimens of those species. Although it is uncertain what share of those damages is attributable to recent imports, that share probably is small, as most of the introductions occurred years, decades, or even centuries ago.

Nevertheless, it is instructive to add those infrastructure and resource damages to the disease costs directly or likely attributable to current imports in order to gain an overall understanding of the annual damages intentionally introduced wild animals are causing in the U.S. Including the damages attributable to past intentional animal imports, the total estimated costs associated with diseases and resource damages caused by intentionally imported live animals to the U.S. was an estimated $36 billion in 2004. Given that a large share of invasives is not included in these estimates due to lack of information on damages,

even these estimates may be conservative. At least $400 million to $900 million of these costs are attributable to live animals imported in 2003-04.

As pointed out at the beginning of this part, the even greater gap in data on the value of the economic benefits associated with live animal imports makes it impossible to assess the net economic impact of these imports. However, the net impact is not really the issue – reducing the costs from damages associated with imports and the exposure to potentially even larger future damages is. It is in this respect that the current system of import controls fails.

iv. Potential future costs

Future damages from invasiveness or diseases associated with live animal imports may be caused either by known pathogens or invaders or by others still to emerge. Given that the number of species imported into the U.S. with risk factors for human, domestic and wild animal diseases is high, it appears likely that a number of additional future diseases will be emerging.

Future emergence of new animal-borne diseases is likely due to the fact that many zoonotic infectious agents so far are still fairly localized (Defenders, 2007). With the increasing volume in international live animal trade, vector-bound zoonoses that currently still exhibit a limited distribution compared to human-only diseases and thus are likely candidates for future spread. As a result, zoonotic pathogens are disproportionately likely to be associated with emerging diseases (Taylor et al., 2001). The importance of zoonoses for human health concerns can hardly be overstated: Out of 1,415 identified infectious organisms known to be pathogenic to humans, 61 percent are zoonotic (Taylor et al., 2001), and 11 of the last 12 significant human epidemics have been due to zoonotic pathogens (Torrey and Yolken, 2005).

The danger is not just to human health, but to domestic and wild animals and ecosystems. For example, as Haydon et al. (2002) point out, about 75 percent of infectious agents found in livestock also occur in other host animals, increasing the likelihood that livestock infections will be unintentionally introduced with imported animals. In turn, many of the agents that affect livestock also affect wild ruminants, such as white-tailed deer, elk and bison.[41]

Because the vast majority of imported wild live animal species are not U.S. natives – 85 percent of vertebrates and 82 percent overall (Defenders of Wildlife, 2007) – a significant proportion of the infectious agents they harbor likely are also foreign to humans, domestic animals and native animals in the U.S. This is particularly important because native populations lack the benefit of prior host-pathogen co-evolution and therefore may lack the benefit of immune defenses with which to fight the new pathogens. Depending on the infectious agent, individual impacts can scale up to pose broad implications for domestic public, animal and ecosystem health. In the remainder of this section, we highlight four of the known animal-borne diseases that constitute major potential threats for the U.S.

[41] Heartwater and other exotic diseases transmitted by arthropod vectors serve as examples of diseases that affect both wild and domestic animals.

Highly Pathogenic Avian Influenza (HPAI)

The potential impacts of highly pathogenic Avian influenza (HPAI) depend fundamentally on whether they stem from an outbreak in poultry like those presently recurring in parts of the world, or a human pandemic involving human-to-human transmission.

A poultry-based outbreak that does not develop into a human pandemic represents a much less grave scenario, though it still has the potential to cause large economic losses. As discussed earlier in this part, the small outbreaks in the U.S. in 2004 caused economic losses of around $70 million in lost export revenues and destroyed poultry flocks and millions of dollars in expenditures on control efforts by federal and state agencies. Larger outbreaks could cause impacts an order of magnitude higher. For example, the 1999-2000 avian flu outbreak in Italy led to the destruction of 16 million birds, with associated direct costs estimated at €112 million ($139 million) and indirect costs of up to €400 million ($500 million) (CREV and IZSVe, 2004). A 2003 outbreak (also in Italy) was even more costly, causing the destruction of 32 million birds and associated direct losses alone estimated at €300 million ($370 million) (all at 2004 prices; CREV and IZSVe, 2004).

Though the potential impact of a large poultry-based AI outbreak is large, it pales in comparison to the potential impacts of a human HPAI pandemic. Those impacts vary widely with the severity of the pandemic. According to recent estimates, an HPAI pandemic could have a global economic impact reaching from 0.7 percent to 4.8 percent of world GDP in the first year, depending on its severity (Burns et al., 2006).[42] The Institute of Medicine of the National Academies estimates the mean economic impacts of a pandemic in the U.S. in the absence of large-scale immunization campaigns at $87 - $203 billion (2004$) for gross attack rates of 15 and 35 percent, respectively (Knobler et al., 2005). Others expect impacts of a severe pandemic to reduce U.S. GDP by as much as 5.5 to six percent in the first year of the pandemic (McKibbin and Sidorenko, 2006; Congressional Budget Office, 2006), which in 2006 would have amounted to $730-800 billion. These costs can be lowered through implementation of a large-scale immunization preparedness campaign and capacity creation, estimated to cost between $110 million to $2.7 billion per year, depending on the cost and effectiveness of the vaccine, the gross attack rate and the probability of a pandemic in any given year.

It is very likely however that such a pandemic, if it were to occur, would spread to the U.S. through human-to-human infection, with imported live animals representing a less likely pathway.

Heartwater disease

Heartwater is an infectious, noncontagious, tick-borne disease of domestic and wild ruminants that affects cattle, sheep, goats, antelope, buffalo and other species. The disease is caused by a parasite and is transmitted by a number of species of ticks in the genus *Amblyomma*. Heartwater is usually an acute disease and generally is fatal within a week of onset of clinical symptoms. The disease is widespread in most of Africa, where it is one of the most important livestock diseases, and on several islands in the West Indies. With increased trade and movement of animals in today's global market, USDA's APHIS judges

[42] In 2006, such an impact would have amounted to losses of between $350 billion and $2.4 trillion globally, mostly from loss of live, but also from lost productivity, medical and control costs.

Heartwater to present a potentially significant threat to the domestic livestock industry in the United States (APHIS, 2002).

The ticks that function as disease hosts enter the U.S. primarily through imported reptiles (Burridge et al., 2000). However, birds or exotic game species (e.g., wildebeest) imported from Africa that have developed widespread resistance to the disease may also serve as pathways. In a recent study aimed at documenting the extent of introduction of exotic ticks on reptiles imported into Florida, exotic ticks were identified on 91 percent of 32 reptile premises in 18 counties (Burridge et al., 2000). Among the eight exotic tick species found, *Ablyomma* species that are vectors of Heartwater disease were found on 28 percent of premises examined.

In experimental tests it has been shown that white-tailed deer are susceptible to infection and also can carry the host, thus constituting a mayor potential pathway for the rapid spread of the disease (Center for Food Security and Public Health, 2006). Thus, Heartwater is one of a number of exotic arthropod-borne diseases that represent potentially considerable threats to the U.S. livestock industry (Bram et al., 2002). In a 1993 report, the USDA estimated that a Heartwater outbreak in the United States could cost the livestock industry $762 million ($983 million in 2004$) in losses annually (Emerging Pathogens Institute, 2006).

In addition to these diseases and others discussed in this part, there are a number of other known or newly emerging zoonotic infectious diseases (Smolinski et al., 2003), many of which have the potential to reach the U.S. via animal imports, or already have done so on previous occasions, such as Ranavirus, Chytridiomycosis, Malignant Catarrhal Fever (Defenders of Wildlife, 2007).

IV. Correcting economic inefficiencies in the current system of managing live wild animal imports to the U.S.

Live wild animal imports generate large economic impacts, both positive and negative. These impacts comprise both market impacts and non-market impacts. Given the large number of impacts and the difficulty of attaching accurate quantitative value estimates to them, it is not possible at this time to assess on the basis of available information whether or not live wild animal imports generate *net benefits* to the U.S. What is clear, however, is that a substantial portion of the costs associated with live animal imports is not borne by the beneficiaries of these imports, but by society at large. Moreover, the costs society incurs from animal imports are unnecessarily high. Society as a whole would receive net economic benefits from an improved system of live animal import regulations that increases the likelihood of preventing the entry of harmful species. The two crucial questions therefore are: What would an optimal live animal import system look like? and How could economic efficiency and equity be improved through a redistribution of the costs associated with live animal imports?

Federal and state agencies are spending hundreds of millions of dollars per year on activities to prevent the arrival of potential invaders and survey for and control the impacts of those that have made it into the country. These activities are virtually all financed out of tax dollars by society at large.[43] Likewise, resource damages as well as health costs, in the form of medical expenditures, lost income and productivity and pain and suffering associated with diseases introduced by imported live animals are borne in part by individuals who neither own imported animals nor otherwise benefit from their importation. Similarly, costs and benefits of live animal imports are not necessarily shared equitably among the beneficiaries of those imports, as bad practices by some actors impose costs on others. The system is characterized by what in economic terminology is referred to as externalities, or third-party effects – individuals (importers, wholesalers and retailers and owners or users of imported animals) do not bear the full economic consequences of their actions because some of the impacts are borne by others not party to the transactions. This leads to inefficiently low market prices of imported species or their carriers because market prices do not reflect the cost these species impose on society as a whole (Perrings et al., 2002). As a result, at present the outcome of the importation of live animals to the U.S. must be characterized as both economically inefficient and inequitable.

Figure 4 provides a graphic example of the externality issue. Again, let us assume that the demand (D) and supply (S) schedules represent the market for imported live animals. The supply of imported animals is a function of the production cost of sellers of imported animals. These sellers base their pricing (supply) on their marginal private production cost (C_P). Given the supply function S, which represents the combined supply from all sellers, and given the demand for imported animals D, a total quantity of imported animals of q is transacted on the market at price p. At this quantity and price, the sum of net benefits (benefits minus costs) to sellers and buyers of imported animals equals the sum of the solid green area (BP) and the red-and-green shaded area. Some of this net benefit goes to sellers in the form of profits, some to buyers in the form of consumer surplus. Imports carry private

[43] APHIS charges importers user fees for inspection services. However, these cover only a share of the costs associated with the agency's prevention activities, and none of the control costs (USDA, 2006).

costs equivalent to the shaded red area *CP*. However, the true cost of the imported animals is not represented by the private production cost curve of the sellers, C_P, but by the social cost curve, C_S. This curve represents all costs to the buyers and sellers of imported animals, plus the cost to third parties, such as private individuals and companies and government agencies. At the imported quantity of animals, *q*, society as a whole incurs costs equal to the area under the C_S curve, that is, the sum of private production costs (*CP*) and externalized (third party) costs, which equal the sum of the area *CS* and the red-and-green shaded area.

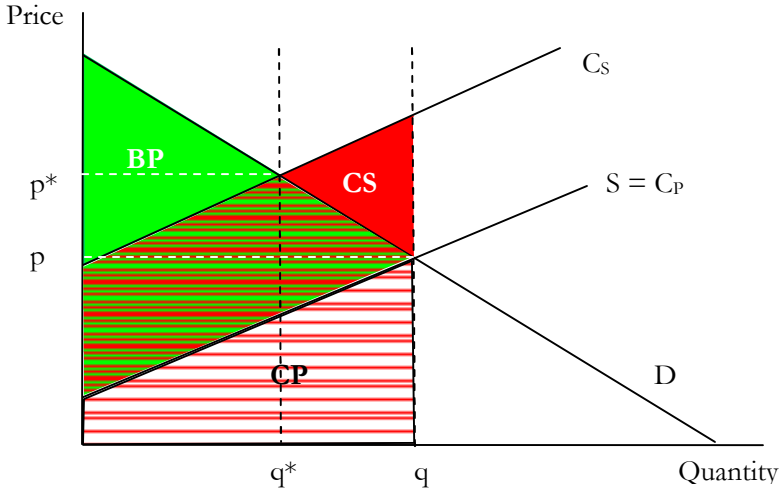

Figure 4: Diagrammatic representation of social costs (C_s) and social benefits (B_s) of animal imports

In this example, the total cost to third parties is actually higher than the total private cost. Total benefit to society as a whole still is somewhat larger than total social cost (area *BP* is larger than area *CS*), but the imported quantity is economically inefficient.[44] It is inefficient because by reducing imports to the quantity *q** (accompanied by a price increase to *p**), total costs would decrease by more than total benefits would decrease, implying that total net benefits from imports to society as a whole could be increased by reducing the quantity of imports to point *q**.[45] However, sellers of imported animals have no incentive to reduce imports, because they (and the buyers of imported animals) do not face the full costs associated with those imports. In the presence of externalities, the quantity *q* of imported animals is benefit-maximizing for suppliers, even if it is too costly from a social perspective.

The negative externalities from animal imports occur because many of the damages associated with these imports affect public goods, that is, goods that are non-rival and non-exclusive and thus are underprovided by free markets. The public goods affected by animal imports include biosecurity and biodiversity (Perrings et al., 2000; 2002). Moreover, the public good of biosecurity is of the weakest-link variety (Horan et al., 2002; Perrings et al., 2000), that is, the benefits of control depend on the level of control exercised by the least

[44] The quantity referred to here is the sum total of all specimens of all imported species.

[45] The net economic benefits would derive from the screening out of the most damaging species (those characterized by high invasiveness potential and associated potential damages) and/or the most damaging specimens of a given species (disease carriers).

effective member of society. Thus, there is a strong argument for public intervention in invasives control efforts (Perrings et al., 2000; 2002).

Economic theory offers three basic approaches to correcting an externality problem:

1) Command-and-Control approaches – these are standards of any form, such as import restrictions and inspection requirements, which aim to prevent, or reduce the likelihood of, introduction of harmful species (i.e., invasive animals and associated pathogens);

2) Economic incentives – comprising taxes or charges and tradable permits, which aim to reduce the volume of an undesired outcome from production (e.g., emission of pollutants) by imposing corrective payments on producers that lead to an internalization of the negative externalities, or, in the case of permits, by limiting the permitted level of the activity outright;[46] and

3) Property rights-based approaches, which aim at eliminating constraints that prevent property rights from being well-defined.[47] Property-rights based approaches comprise insurance requirements, bonding requirements, civil fines and criminal penalties and fines.

All three of these approaches, assuming for the moment their implementation is feasible in the case of imported animals, could be used to redirect some of the third-party costs caused by live animal imports onto the beneficiaries from these imports. Graphically, this would result in an upward shift of the private cost curve, C_P, towards the social cost curve, C_S. The magnitude of the shift depends on the portion of uncompensated third-party costs that is shifted onto suppliers and users of imported animals. As already pointed out, such a reassignment of costs from society at large to the individuals whose actions cause the costs would both increase social equity and improve economic efficiency, by lowering imports to somewhere between the current level q (at price p) and the economically efficient level q^* (at the efficient price p^*). The size of the correction obviously depends on the quality of the policy design and the degree of policy implementation.

Out of these three approaches – standards, taxes and property rights, only the first two would seem suitable in the case of live animal imports. Property rights approaches such as insurance or bond requirements, civil fines, and criminal penalties and fines, probably are not as well-suited to addressing the problem of invasive species, because time- and spatial

[46] Import inspection fees do not belong into the economic incentive category as they simply represent a payment for a specific service provided by government. Full compliance with live animal import standards might necessitate higher fees to ensure rigorous compliance with standards, which might entail inspection of a significant percentage of all shipments. Though this might displace some imports that would become unprofitable at higher fee levels, this does not make the fee an economic incentive instrument, as the latter is intended to influence behavior. A fee does not have this purpose; rather it is intended to cover the costs government incurs by enforcing standards.

[47] Well-defined property rights are complete (i.e., the owner can capture all types of benefits derived from a good or service), exclusive (i.e., others can be prevented from enjoying these benefits), transferable, and reliably and cheaply enforceable (Randall, 1987). In the case of invasives, the property rights of third parties are not well-defined because at least one of the four conditions often is not fulfilled. Thus, third parties often cannot use legal action to correct infringements on their property or health caused by damages associated with imported species.

lags and missing information often will make identification of culpable individuals and legally acceptable proof of cause-and-effect problematic or impossible (Jenkins, 2002). That leaves standards and taxes as potential instruments.

Corrective taxes on polluting behavior that causes uncompensated third-party or "spillover" effects have long been promoted by economists. Commonly referred to as Pigouvian taxes after A.C. Pigou who first developed the formal concept of externalities (Pigou, 1932), such corrective taxes are set at such a level that they are exactly equivalent to the gap between the social cost and the private price of a polluting good, thereby making producers face the full costs of their actions. Such internalization of negative third-party impacts is efficiency-promoting and lies at the heart of the "polluter-pays" principle.[48]

While theoretically straightforward, optimal Pigouvian taxes are difficult to design in practice because much of the information required for setting them at the correct level often is not available. Specifically, imposition of an optimal (i.e., efficient) tax requires knowledge of the exact shape of the spillover cost curve, which in turn requires perfect information about present and future damages from live animal imports. Such information is not available. As a result, optimal Pigouvian taxes on animal imports do not seem feasible, at least not until reasonably accurate information on damages is available.

This, however, does not mean that the market failure caused by the uncompensated third-party effects cannot at least be reduced. In other words, even though *optimal* taxes may be beyond reach, it is still possible to implement (second-best) taxes that internalize *some* of the spillover damages and thus to some extent correct the wrong price signals given by the live animal import market. The idea of charging "polluters" for costs associated with imported species of course is not a new one. For example, Carlton (2001, p. 24) suggested that Congress impose a "national bioinvasions reparation fee" on industries that play a fundamental role as vectors in transporting non-native species, with the revenue generated being used to fund federal management, research and development programs. Similarly, Jenkins (2002) calls for leveling "biological pollution risk reduction fees" on the three main economic categories of intercontinental introduction pathways for invasive species, including imports of live goods.[49] Since the taxes would be leveled on imported live animals only, it would likely be administratively easier to make them take the form of import tariffs. As Margolis et al. (2005) argue, market failure and external costs imposed by invasive species

[48] The "polluter-pays" principle, adopted by the OECD (1972) in the early 1970s, stipulates that charging sources for polluting is the best way to achieve internalization of negative spillovers into the market-price mechanism. Since polluting firms pass on all of part of the increased production costs (for prevention and control expenditures and pollution charges), implementation of the principle thus leads to responses by both producers and consumers that improve the allocative efficiency of the market. Since the "polluter-pays" principle aims at improving resources use efficiency, it is different from legal liability rules that make polluters responsible for compensation for specific damages to human health or property.

[49] An example of such a fee is California's Ballast Water Management and Control Program, which charges a $200 fee for each ship that enters its ports. The revenues generated are used to support inspections aimed to ensure ship captains' compliance with state ballast water rules and to support the California Exotic Species Control Fund, which supports research, monitoring, and education to improve prevention efforts (Jenkins, 2002). Hawaii's Senate recently passed a bill that would charge one dollar for each container landed in the state and would establish an invasive species inspection, quarantine, and eradication fund (Hawaii Senate, 2007).

may justify such import tariffs.[50]

The second approach available for addressing the failures of the current live animal import regime are improved and more rigorously implemented standards. These standards should be based on a comprehensive risk assessment of the potential damages that may be caused by a particular species. Currently, no rigorous risk assessment exists for U.S. species imports. Fowler et al. (2007) suggest that the Fish and Wildlife Service should be directed to conduct a mandatory comprehensive pre-screening of all species proposed for importation into the U.S. According to the recommendations in Defenders' (2007) *Broken Screens* report, based on the results of that pre-screening, species should be classified as either allowed, non-provisionally prohibited, or provisionally prohibited pending further information, and placed on corresponding "clean", "dirty" or injurious, or "gray" lists. The IUCN Invasive Species Specialist Group (2007) working with Defenders of Wildlife (2007) recently completed a coarse risk screening identifying species with the potential to become invasive in the U.S. This work could form the preliminary basis for such a categorization of imported species, leading to a "finer"-level risk ranking for the preliminarily-identified species.

Application of the "three-list" approach should be based on a precautionary approach as operationalized for example in the form of the Safe Minimum Standard (Ciriacy-Wantrup, 1952; Bishop, 1978). The Safe Minimum Standard approach proposes that renewable resources should be preserved and maintained at a level that is expected to preclude extinction, unless the social costs of doing so are prohibitive or "immoderate." Its application is often advocated in situations where an outcome of an action is characterized by high uncertainty and irreversible, potentially catastrophic consequences (Perrings, 1991). In the case of invasive or disease-carrying animals, such potentially disastrous outcomes could take the form of extinctions of native species, infectious human pandemics, or large economic losses from lost output, trade, or eradication campaigns.

Importantly, this clean/dirty/gray three-list approach is allowed under international trade rules, provided specific requirements as to the composition of the dirty and gray lists are satisfied.[51] It has been successfully applied to plants in Australia, New Zealand and elsewhere (Jenkins, 2005).

The three-list approach could be expanded into an economic or risk assessment of the costs and benefits expected to result from the importation of each species. The resulting cost-benefit analysis of pre-screening imported species would consider both the costs of the pre-screening, namely, the resource cost of administering the pre-screening program and the benefits foregone by excluding species, and the benefits from pre-screening, namely, the reduction in expected damages from invasions.[52] Simply put, for the pre-screening test to

[50] However, the authors also point out that pressures of political economy will tend to make the tariff suboptimally high. The resulting disguised protectionism may withstand scrutiny under World Trade Organization rules because international agreements on sanitary and phytosanitary measures include provisions that allow imposition of trade barriers on scientific grounds. It may be difficult to prove in a given case that import tariffs are in fact protectionist and not scientifically-based (Margolis et al., 2005).

[51] For a discussion of the compatibility of the three-list approach with international law, see Jenkins (2007).

[52] Kaiser (2006) argues that prevention efforts should be based on the expected outcome if prevention fails, because no prevention program is likely to be perfectly effective. As a result, over time, the cumulative probability of a new species invading and establishing itself is nearly one.

produce net economic benefits, the product of the likelihood ratio of the screening process (its predictive power to identify potential invaders), the probability that an introduced species will become a pest, and the expected cost if it does so, must be at least equal to one (Perrings et al., 2000).[53] As Perrings et al. (2000:233) point out, such an ex-ante cost-benefit analysis of a pre-screening process is very different from ex-post assessments of the net benefits generated by effective controls, because the latter are "tantamount to calculating the value of a winning lottery ticket" – they do not consider the foregone benefits associated with wrongly excluded non-invasive species.[54]

Keller et al. (2007), in the first actual implementation of a cost-benefit analysis of an import pre-screening program, develop a pre-screening-based risk assessment for the Australian plant quarantine program and show that such an assessment is likely to produce large net economic benefits. They further suggest that pre-screening protocols might generate even higher net benefits for animal imports because of animals' higher rates of invasion.

Effective implementation of import standards of course requires a sufficiently rigorous monitoring and inspection regime coupled with the credible threat of sufficiently deterring sanctions in the case of non-compliance. Most likely, those sanctions would take the form of monetary penalties or withdrawal of import licenses, where applicable.

Of course, prevention is just one part of an invasives control strategy. The other is control – i.e., detection, containment, reduction or eradication of an invasives species. As a result, the optimal allocation of resources on an invasives strategy involves not only the decision on whether or not to screen, but on how much to invest in screening vs. control efforts (Perrings et al., 2000; Mehta et al., 2007).[55, 56] In economic terms, the challenge is to identify that strategy to invasives management, including prevention and control, which minimizes the overall invasives-related costs over time, that is, the strategy that minimizes the sum of present value net damages from invasives and from their prevention and control (Kaiser, 2006).[57] Invasives research has been focused almost exclusively on the impact of existing invasions, with prevention largely unaddressed (Leung et al., 2005), thereby failing to provide guidance of prevention and control efforts; the result appears to be an underinvestment in prevention for many potential and actual invasives (Leung et al., 2002). Research suggests that risk-averse managers usually under invest in prevention in favor of control, because of

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[53] For a formal presentation of the cost-benefit decision calculus of pre-screening see Perrings et al. (2000).

[54] There are a large number of analyses that assess the economic net benefit or benefit-cost ratios of successful control or prevention of invasive species. These generally document that control or prevention of particular invasions have generated high economic returns (benefits) on investment (cost). See summaries in OTA (1993) and Hill and Greathead (2000).

[55] For a conceptual model of the prevention-control tradeoff and an applied example see Leung et al. (2002).

[56] Cost-effective management of invasives requires the integration of biological/ecological analysis and human values (Lodge and Shrader-Frechette, 2003; Goodhue and McKee, 2006). Failure to consider both costs and benefits of invasives and failure to include both market and non-market values prevents cost-effective societal investments in prevention and control of invasives (Leung et al., 2005). Generally, human values so far have not been adequately incorporated into analyses of both prevention and control (ibid.).

[57] In general, expenditures on preventing invasion of a new species should continue until the point at which the marginal control costs for both actions are equal, that is, until the cost of preventing the next specimen from entering equals the cost of controlling another specimen already entered (Kaiser, 2006). Strategies for fast-spreading species may require comparatively more prevention efforts, while slow-spreading species may favor a strategy more balanced towards control.

the uncertainty over the effectiveness of prevention efforts (vs. the certainty of control efforts that targets actually present specimens) (Finnoff et al., in press). To improve the efficiency and effectiveness of society's overall invasive control efforts, general, straightforward decision rules of thumb for prevention and control policy-making based on easily-understood and estimated parameters are being developed (Leung et al., 2005).

Correcting or reducing the inefficiencies in the current system of live animal imports through species pre-screening would reduce the economic costs to society of species imports. Returning to our diagrammatic example, pre-screening would have the effect of shifting the social cost curve of species imports (C_S) downward to C_S' (Fig. 5).

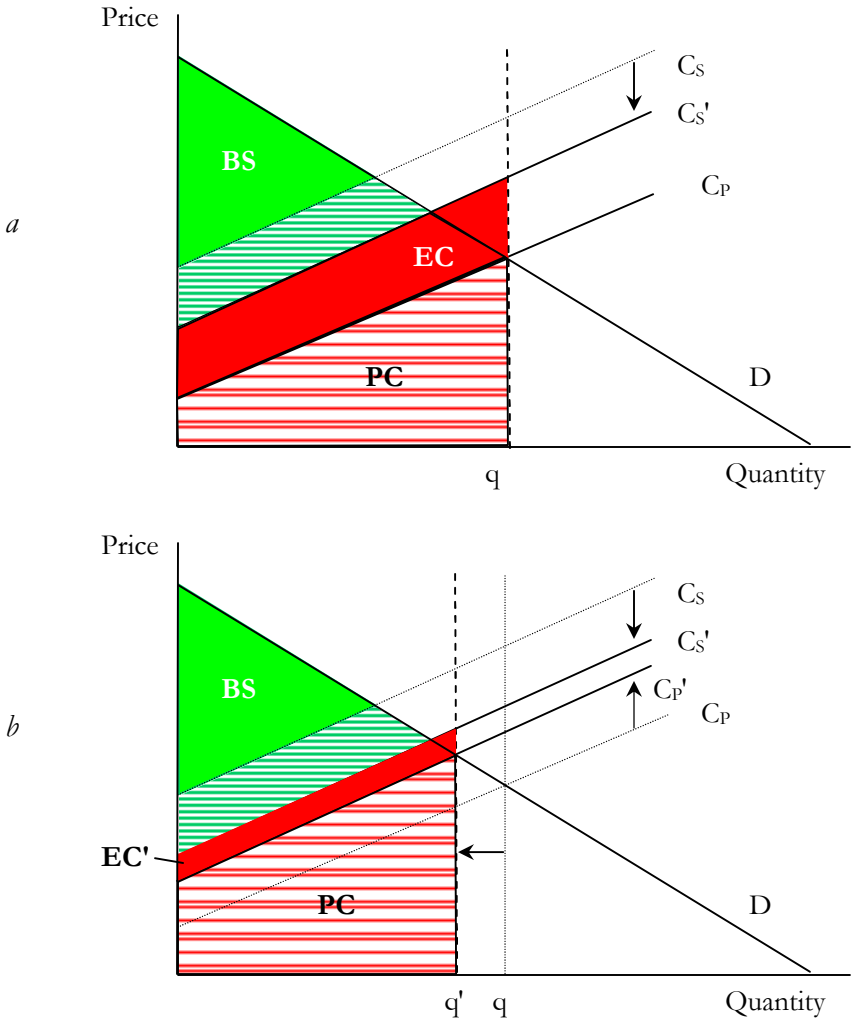

Figure 5: Diagrammatic representation of the impact of pre-screening of animal imports

Thus, external costs (*EC*) as well as total social costs (sum of external costs, *EC*, and private costs, *PC*) from animal imports would be reduced. If the pre-screening program is well-designed, its costs would be more than offset by reduced damages from invasions, yielding net benefits to society. Importantly, if it is financed through taxes on industries associated with live imports, the resulting upward shift of the private cost curve (C_P') will further reduce

inequities associated with uncompensated third-party damages from imported animals. The combined effect of an import pre-screening system and taxes on industries involved in live animal imports is shown in panel *b* of Figure 5. Combined, the two policies reduce economic inefficiencies and inequity of imports: the reductions in the quantity of imports have brought about reductions in costs that are larger than reductions in benefits, while external costs also have decreased (from EC to EC').

From an economic perspective, then, the best feasible approach would be to combine import standards based on a pre-screening risk assessment, coupled with the effective implementation of a rigorous import inspection regime and compliance-inducing sanctions for import violations, with externality-reducing taxes on imported animals. By incorporating both risk-aversion and uncertainty, such a combined approach could be constructed to adequately address both the economic efficiency and the equity failures present in the current live animal import system. Of course, incorporation of uncertainty into the risk management decision calculus is not easy, but the literature provides suggestions as to how this might be done (e.g., Horan et al., 2002).

V. Conclusions and recommendations

The purpose of this analysis was to compile estimates of the economic impacts associated with live animal imports. Although data gaps prevent a comprehensive estimate of the costs and benefits to the U.S. from live animal imports, sufficient information does exist to show that these imports generate economic impacts in the billions of dollars per year, both on the cost and the benefit sides.

Crucially, many of the damages imposed by live animal imports likely could be substantially reduced. These damages principally result from failures of the current system of import regulations to screen out invasive or otherwise harmful species, including disease carriers (Defenders of Wildlife, 2007). As a result of these failures, the current system of live animal imports promotes a situation that is both inefficient and inequitable. It is inefficient because large net benefits could be gained by society as a whole from correcting the failures of the import system. It is inequitable because it imposes a large share of damages associated with live animal imports on third parties that are neither directly nor indirectly involved in live animal imports and that do not benefit from these imports. These costs are incurred either by individuals (people and firms) directly, in the form of medical expenses, lost income, premature death and pain and suffering from infectious diseases carried by imported animals or from infrastructure and resource damages caused by these imports, or borne by them indirectly in the form of tax payments to finance control efforts by local, state and federal agencies.

Given the large data gaps, our estimates of the costs imposed on the U.S. in 2004 by diseases associated with live wild animals intentionally and legally imported into the U.S. in 2003-04 (2004 being the most recent year for which data on numbers of live animal imports are available) range from $400-$900 million. The lower end of the estimate only includes the costs from animal-borne diseases conclusively linked to current (2003-2004) live wild animal imports, and only for the two most costly diseases – exotic Newcastle disease and reptile-associated salmonellosis. The upper end of the estimate also includes the costs of disease outbreaks potentially but not definitively linked to imported animals, including avian influenza and West Nile virus. Neither the low nor the high estimate includes the cost of infrastructure and natural resource damages caused by imported species. Based on Pimentel et al.'s (2005) study, the damages caused by intentionally introduced non-native animal species in the U.S. amount to an estimated $35 billion per year. However, these costs represent the impacts from the complete current populations of existing non-native alien species intentionally introduced (or, rather, the portion of these species included in Pimentel et al.'s analysis), not only from those specimens of these species introduced during 2003-2004, the period analyzed in our study. It is not possible to estimate the share of these damages that can be attributed to 2003-04 live animal imports. Nevertheless, this share certainly is larger than zero. Moreover, neither disease costs nor resource damages include the negative impacts of invasive imported animals on native biodiversity. Thus, the actual economic costs associated with live animal imports in 2004 almost certainly were higher than $400-$900 million. Most importantly, these costs were much higher than they needed to be.

The economic inefficiency and the inequity inherent in the current live animal import system could both be reduced substantially through eminently feasible measures. They both result from the failure of the current system to adequately internalize the negative spillovers (i.e.,

externalities, or third-party impacts) of animal imports. Society as a whole could benefit enormously if importers and users of imported live animals were forced to confront the full costs, or at least a larger share of the full costs, associated with these imports.

The redesign of the current system of import regulations should not be delayed in search of the "perfect" system. The complexity of social and biological system and their interactions, data limitations, and uncertainty will always prevent perfect information and complicate standard economic policy analysis (Evans, 2003). Sufficient information is available to greatly improve the current system of live wild animal imports.

The prescription to overcoming the shortcomings of the present system is fairly straightforward: implement (a) a comprehensive risk assessment (pre-screening) of all imported species, coupled with substantially improved reporting requirements (Weigle et al., 2005); (b) sufficiently deterring fines for violations of reporting requirements and import regulations (accompanied by associated higher fines or criminal prosecution for illegal importation to avoid pushing more imports underground); (c) an effective inspection and quarantine regime; and (d) the financing of these efforts through fully cost-covering inspection and quarantine fees and the imposition of corrective taxes on sales of imported live animals or, alternatively, tariffs on imported live animals. Pre-screening of all imported species through a comprehensive risk assessment system is not only technically feasible and would generate large net economic benefits (Keller et al., 2007), but initial efforts that could serve as a basis for a full risk assessment of live animal imports to the U.S already have been completed (Defenders of Wildlife, 2007). Implementing a strong and continued risk assessment system also would be a wise investment to reduce the risk of costly surprises from future emerging diseases.

As pointed out in a recent position paper by the Ecological Society of America (Lodge et al., 2006) and demonstrated by research (Keller et al., 2007), implementing the suggested corrections of the failures in the current live wild animal import system is both feasible and would be economically beneficial.

VI. Literature cited

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