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NON-NATIVE SPECIES *DO* THREATEN THE NATURAL ENVIRONMENT!

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ABSTRACT. Sagoff [*Journal of Agricultural and Environmental Ethics* 18 (2005), 215–236] argues, against growing empirical evidence, that major environmental impacts of non-native species are unproven. However, many such impacts, including extinctions of both island and continental species, have both been demonstrated and judged by the public to be harmful. Although more public attention has been focused on non-native animals than non-native plants, the latter more often cause ecosystem-wide impacts. Increased regulation of introduction of non-native species is, therefore, warranted, and, *contra* Sagoff's assertions, invasion biologists have recently developed methods that greatly aid prediction of which introduced species will harm the environment and thus enable more efficient regulation. The fact that introduced species may increase local biodiversity in certain instances has not been shown to result in desired changes in ecosystem function. In other locales, they decrease biodiversity, as they do globally.

KEY WORDS: biodiversity, ecosystem function, introduced species, invasion, non-native species, prediction, risk assessment, Sagoff

1. INTRODUCTION

Repeating a claim he has made often (see, e.g., Sagoff, 1999, 2000), Sagoff (2005) contends that the notion of introduced species as an environmental problem is overblown and that arguments pointing to great environmental impacts from non-native species (NNS) rest on both poor science and imprecise terminology, culminating in a tautology. This is a remarkable claim, given the rapidly increasing attention NNS have received from both scientists and society at large (see, e.g., Simberloff, 2004), but not a unique one (cf. Burdick, 2005). Sagoff (2005) sees five problems with the traditional view of NNS as a conservation menace, and he finds that two of these problems would prevent an effective response to NNS as a general phenomenon even if one were to concede that they might be problematic in particular cases.

2. HARM, INCLUDING EXTINCTION

First, Sagoff (2005) argues that, when ecologists say an NNS "harms the natural environment," the term "harm" is nebulous and undefined, and that it is, therefore, impossible to show that NNS are more likely to cause environmental harm than native species or than species at random. Second, he asserts that ecologists cannot predict how NNS will behave in the wild. In his view, the first problem renders the motive for the entire enterprise of confronting introduced species suspect, while the combination of these two problems would make it impossible to regulate introduction of NNS effectively because policymakers would have to target all NNS as potentially harmful, a task he sees as hopelessly large.

It is indeed true that a statement that an NNS harms or will probably harm the environment is vague and imprecise. However, this fact, as adduced by Sagoff (2005), is a red herring, because the vast literature describing impacts of particular NNS details the specific kinds of harm. The catalog is so long that it cannot be reproduced in a short article (see Williamson [1996] and Cox [1999] for summaries), but the fact is that NNS have environmental impacts at both the population and ecosystems levels, and those impacts have often been demonstrated to reduce the size of native populations (sometimes to the level of local or global extinction) and the extent of native ecosystems (again, often to the level of local or global disappearance). The population level impacts arise by such interactions as predation, herbivory, parasitism, disease, competition, and hybridization, while ecosystem level impacts entail such phenomena as drastically changed nutrient cycles, hydrological or fire regimes, or habitat structure. Ecosystem impacts are much more commonly caused by introduced plants, and they are usually more consequential than single population impacts in terms of "harm" to the environment because, by changing the entire habitat, they affect many species all at once. However, they receive less attention in the lay press, probably because there is little a plant can do that is as photogenic and gripping as a brown tree snake eating a bird or a sea lamprey clinging to a fish.

Sagoff (2005) appears to concede (why, exactly?) that extinction is undeniably "harm," but he contends that NNS are not a "significant" cause of extinction except on small islands or insular habitats. This is the third problem he sees with the conventional view of NNS. And, to him, a simple decrease in a population size or reduced extent of a population or ecosystem is not inherently harmful; after all, nature is dynamic and populations and ecosystems wax and wane all the time.

This is a complex set of arguments. To begin with, his contention that NNS do not cause much extinction is both incorrect and misleading. He cites Gurevitch and Padilla (2004) to the effect that "available data supporting invasion as a cause of extinctions are, in many cases, anecdotal, speculative and based upon limited observation.'' What he fails to mention (and so did Gurevitch and Padilla) is that exactly the same statement could be made about every claimed cause of extinction – habitat destruction, pollution, disease, etc. The disappearance of the last individuals of a population is usually not observed, and very few populations in nature are studied sufficiently exhaustively to allow more than speculation about why they are declining. Yet, the overwhelming consensus of ecologists and systematic specialists who study them is that NNS are a highly significant factor in endangerment and extinction – indeed second only to habitat destruction by most tallies.

A good representative recent example is the exhaustive tabulation of threats to birds (BirdLife International, 2000) compiled by an international team including some of the world's leading ornithologists. Birds as a whole are far better studied than any other large taxon, so much more information is available. Of 1186 bird species threatened with imminent extinction (ca. 12% of the total world avifauna), 510 (almost half) are threatened wholly or partly by introduced species. Of these, 298 are threatened by introduced predators, but the whole threat does not come from predators, as Sagoff (2005) implies. Introduced competitors threaten 72 bird species, introduced herbivores 71, and introduced plants 69. It is true that many of these invaders and threatened birds are on small islands, but island birds are a large fraction of all birds; ca. 17% of all species are restricted to islands and many others are primarily on islands. Further, NNS threaten many continental birds. For example, the malleefowl (*Leipoa ocellata*) in Australia is threatened by grazing by introduced herbivores such as sheep and predation by introduced foxes, while all European populations of the white-headed duck (*Oxyura leucocephala*) are threatened by competition and hybridization with the introduced ruddy duck (*O. jamaicensis*). An important feature is that threats from NNS are often multiple. Among birds, for example, the Tahiti monarch (*Pomarea nigra*) is threatened by the replacement of much native forest by the introduced invaders *Miconia calvescens, Spathodea campanulata*, and other NNS, and predation by introduced black rats (*Rattus rattus*) and introduced birds such as the red-vented bulbul (*Pycnonotus cafer*) and common myna (*Acridotheres tristis*) also contribute to its grave state.

Sagoff (2005) repeatedly cites Gurevitch and Padilla (2004) to the effect that NNS are not a major cause of threat or extinction. These authors argue that, on the IUCN Red List database (2003), only 6% of taxa are threatened by NNS and only 2% of extinctions resulted from NNS. Among others, Clavero and García-Berthou (2005) have rebutted this claim, showing it to be extremely misleading. The IUCN lists causes of only 39 of 762 known recent extinctions. For instance, for birds, there are 129 recent extinctions, and IUCN assigns a cause to none of them, despite the existence of strong evidence for a key role of NNS in many of them (e.g., the elimination of robust white-eye, *Zosterops strenuus*, after the black rat arrived on Lord Howe Island). For the 680 known animal extinctions in the list, Clavero and García-Berthou found in a case-by-case study that causes could be strongly inferred for 170, of which 91 included NNS. For 34 of these 91 extinctions, NNS were the sole cause. Similar studies of known causes of fish (Miller et al., 1989) and mammal (McPhee and Flemming, 2004) extinctions yield similar results.

The issue of whether population or ecosystem decline short of total disappearance can be considered ''harm'' is a difficult one, for the same reason that ''harm'' without elaboration of its basis is a problematic foundation for anti-NNS activity. Harm is a subjective concern – harm to whom? I assume the reason Sagoff (2005) does not contest NNS harm to economic interests and to public health is that he feels readers would agree that a phenomenon that acts against the interests of at least some humans is ''harmful.'' It is, therefore, not completely clear why he accepts extinction of a species as harmful (would extinction of smallpox be harmful?), other than that the public generally sees it as harmful (as witness the US Endangered Species Act). It is even less clear why he considers extinction harmful but not drastic change in population size or extent. Neither can I claim that such changes are harmful; I can only point out that public sentiment views them that way (again, witness the Endangered Species Act, as well as many governmental and private activities to preserve dwindling populations and habitats). What is clear is that Sagoff's argument that these changes are within the range of those encompassed in the short term by the normal vicissitudes of dynamic nature is fallacious.

Is it harmful that ca. 300,000 ha of south Florida have changed within 150 years from native sawgrass (*Cladium jamaicense*) and muhly grass (*Muhlenbergia* sp.) prairies, the ''river of grass'' (Douglas, 1947), to virtually monospecific stands of Brazilian pepper (*Schinus terebinthifolius*) trees and shrubs, independently of whether any species go extinct? Society as a whole has said yes, through the actions of the Florida Bureau of Invasive Plant Management, among other entities. This does not mean they are correct and Sagoff (2005) is wrong, but it shows he is in a minority in terms of his value judgments. To take an example closer to Sagoff's home, is it harmful that the Potomac River now has thriving introduced populations of species of carp, largemouth (*Micropterus salmoides*) and smallmouth (*M. dolomieu*) bass, blue catfish (*Ictalurus furcatus*), Asiatic clams (*Corbicula fluminea*), Eurasian watermilfoil (*Myriophyllum spicatum*), hydrilla (*H. verticillata*), and probably Asian northern snakeheads (*Channa argus*)? Probably each species has its enthusiasts and detractors. The one thing for sure is that all of these species arrived with human assistance in little more than a century, and almost certainly none would have reached there in a million years on its own.

Under the rubric "Two Sides to Every Story," Sagoff (2005) acknowledges that different people have different views of "harm" (though only with respect to impacts on nature, not to impacts on the economy or human health). His tallies of benefits and costs are often counter to those in the literature, however. For instance, for purple loosestrife (*Lythrum salicaria*), he cites several papers that he implies show no ecological harm from the plant and compares them to one (Blossey et al., 2001) that sees such harm, as if they are all of equal weight. The paper by Blossey et al. (2001) is more recent and more comprehensive than the others. It is true that early claims that this species was an invasive horror were poorly supported; it is not true that there has been no subsequently developed evidence of damaging impact. To take an animal example of the Two Sides claim, Sagoff (2005) cites Williamson (1996) regarding the Nile perch (*Lates niloticus*) introduction to Lake Victoria: "In biological and environmental terms, this invasion has been a disaster. In terms of feeding the growing human population round the lake, it is a success." Actually, many consider it a disaster in terms of feeding the human population around the lake (Kasulo, 2000). Not only has annual yield of fish dropped up to 50% since the perch was introduced, but the Nile perch fishery is dominated by a few exporters who ship most of the catch overseas, so the "population round the lake" is actually impoverished.

Three other aspects of NNS bear discussion with respect to this issue. First, it often requires rigorous, extended empirical research to determine the impact of an NNS, and few NNS have been subjected to such study. Often species that appeared innocuous turned out, on close examination, to have major impact on one or more native species, sometimes on whole ecosystems. Invasion biologists are in broad agreement that they have detected but a fraction of the existing impacts of NNS. Second, many introduced species have no apparent impact for years, even decades after an introduction, then rather quickly greatly increase in population size and range, often with drastic impact (Crooks and Soulé, 1996). Brazilian pepper, discussed above, was of little consequence for a century before it exploded to dominate much of south Florida (Ewel, 1986). Reasons for these time lags are idiosyncratic and often mysterious, but it is clear that assessments of "no harm" can change greatly quickly. Third, there is every reason to believe that certain ongoing global changes, such as climate change, increased carbon dioxide, and increased nitrogen deposition, will affect impacts by NNS, and most scientific study of the issue (see, e.g., Mooney and Hobbs, 2000) leads to the conclusion that NNS impact will worsen far more often than it will decrease. For instance, many harmful NNS whose geographic ranges are currently limited by temperature will see their ranges expand as temperature increases.

3. PREDICTION

Sagoff (2005) argues that the difficulty in defining "harm" combines with an inability of invasion biologists to predict what NNS will do in natural ecosystems to render any policy of exclusion hopeless. The reasoning is that inability to predict means that any rational approach to permitting entry would require exhaustive study of each species, a hopelessly large task. He goes further to suggest that, as an alternative, invasion biologists – including me (Schmitz and Simberloff, 1997) – have argued for blanket exclusion – "a *carte blanch* against all alien species in natural areas."

First, Sagoff (2005), citing philosopher Kristin Shrader-Frechette (2001), contends that invasion biologists have made no progress since Asa Gray (1879) argued that no traits other than invasiveness itself allow biologists to predict which species will be invasive and which will not. The statement was true when Gray wrote, and probably largely true (with allowances for hyperbole) even as late as the 1970s (Simberloff, 1986), but it is certainly incorrect now. Early efforts were probably aimed at too broad a candidate pool of invaders, but recent attempts focusing more narrowly on groups of species have been far more successful at using a few relatively easily measured species traits to predict with high accuracy which NNS will become invasive and which will not: e.g., Rejmanek and Richardson (1996) and Grotkopp et al. (2002) for pines, Reichard and Hamilton (1997) for woody plants, and Kolar and Lodge (2002) for fishes. This is not to say that all problems are solved with respect to prediction. For most taxa such efforts have not been undertaken. And even for taxa that have been studied in this regard, high success rates in predicting which NNS will become invasive may not satisfy all stakeholders in a permitting process (Smith et al., 1999). However, to assert that biologists have made no progress in over a century betrays an appalling ignorance of the relevant science.

As for the contention that subjecting every potential deliberate import of NNS to scientific scrutiny would be an impossibly onerous task, New Zealand does just that, in accord with its Biosecurity Act of 1993, and the system has worked quite well (Parliamentary Commissioner of the Environment, 2000). Of course, much rests on exactly how much scientific scrutiny is afforded each species, but even a fairly cursory scan by expert invasion biologists can go a long way towards preventing entry of many NNS with high probability of becoming invasive, and application of statistical tools such as those of Rejmanek and Richardson (1996), Reichard and Hamilton (1997), and Kolar and Lodge (2002), cited above, would eliminate many more. There would still be mistakes, but such a system would be a vast improvement over the weak regulatory framework that currently guides entry to the United States. Sagoff (2005) considers the

Lacey Act and Federal Noxious Weed Act, which govern deliberate import of NNS into the United States, as tough laws, but they are actually very weak (Simberloff, 1996). They are reactive and rely on short black lists. Any species not on these black lists – that is, the vast majority of species – can be imported legally, subject to quarantine regulations to prevent entry of pathogens of humans or agricultural products.

Sagoff (2005) quotes from my writings out of context to support his view that scientists are unable to predict and that a call to ban all NNS is therefore warranted. The quote from Schmitz and Simberloff (1997) to the effect that "one can question how much credence to place in a risk assessment" was clearly not aimed at the effort, even in 1997, to assess whether a species is likely to cause harm. Rather, it was a criticism of the requirement for *quantitative* risk assessment imposed by the multilateral trade treaties – the necessity to assign a precise number to the probability that a species will establish in nature and another to the probability that it will cause harm. Such quantification is still not possible, but the exercise of conducting the assessment can be useful in identifying the gamut of possible threats a species might pose and getting a sense of the probabilities that any will be realized (Simberloff, 2005). Finally, nowhere in Schmitz and Simberloff (1997) is there a call for "a *carte blanche* against all alien species in natural environments." Our paper explicitly aimed at identifying more clearly the minority of species that are harmful. It is also a mystery to me how Sagoff (2005) can construe our suggestion that "Every proposed introduction must receive the scrutiny currently reserved for species known to have caused harm elsewhere" as "creat[ing] the impression that conservationists are not particularly interested in sustaining the missions of agencies like APHIS and CDC, which deal with organisms that affect human health and agricultural crops." We strongly support their missions and in no way aimed to undercut them. We simply stated that APHIS, as an arm of the US Department of Agriculture, and CDC, focused on human disease, do not devote nearly as many resources to NNS that might affect natural environments – a complaint that many have advanced, including the US General Accounting Office (2001).

4. BIODIVERSITY, SPECIES RICHNESS, AND ECOSYSTEM FUNCTION

The fourth fault Sagoff (2005) perceives with the widespread alarm over NNS is that, although conservationists often lament that NNS reduce biodiversity, in fact they increase species richness locally, and increased species richness "correlates with desirable ecosystem properties...such as stability and productivity." This argument raises two issues – the actual effect of NNS on species richness and the relationship of species richness to desirable ecosystem properties.

Globally, NNS decrease species richness. Every species that goes extinct because of NNS (see "Harm, including extinction" above) is one fewer species on earth. Sometimes introduced species increase local species richness, and other times they decrease it. Occasionally an NNS can substantially lower local species richness – an example mentioned in a different context by Sagoff (2005) is the brown tree snake (*Boiga irregularis*), which has eliminated almost all the forest bird species of Guam (Williamson, 1996). Such a local decline is more usually caused by a species that affects an entire ecosystem, and these impacts are not restricted to small islands. For instance, in Australia, introduced Asian salt cedar (*Tamarix* spp.), through its hydrological impact, has replaced diverse native plant communities with assemblages consisting of just a few salt-tolerant species, including other NNS (Griffin et al., 1989). However, because most introduced species do not have major impacts (Williamson, 1996), probably by their very presence most NNS increase local richness at least as frequently as they decrease it. There has been no systematic tally of the relative frequency of local species richness increase and decrease.

The net effect of NNS on species richness is captured well by nature writer David Quammen (1998) in his essay "Planet of weeds." Quammen suggests that, a century or more in the future, the earth will still be green and most places will still have lots of species – that is, local species richness will still be substantial. However, whereas nowadays these species sets differ greatly from site to site, especially between continents, in the future there will be largely the same species at each site – the weeds of the world.

Next is the question of how species richness *per se* relates to other ecosystem properties. At the outset, it is striking that Sagoff (2005), who is so concerned about what we actually mean by "harm" to the environment and how we know an impact is harmful, is quite casual with respect to "desirable" ecosystem properties. "Desirable" connotes a desirer, so it is subjective, just as "harm" is. It is not so clear that productivity, to take one example, is always desirable. Eutrophicated ecosystems are often highly productive, but we usually do not desire them. The invasion of the island of Hawaii by the nitrogen-fixing Atlantic shrub *Myrica faya* is fertilizing the soil and leading to the replacement of native trees and ground cover plants adapted to the nitrogen-poor volcanic soil by NNS including grasses as well as *Myrica* itself (Vitousek and Walker, 1989); it is likely that productivity is increasing, but who desires this increase?

In any event, the relationship in nature of species richness to productivity, stability, or other ecosystem properties is highly contested (see, e.g., Huston and McBride, 2002; Wardle, 2002; Srivastava and Vellend, 2005).

Sagoff (2005) dodges this controversy; he says that "species diversity, according to many accounts, positively affects ecosystem functioning," but he says nothing about many accounts questioning this relationship in nature.

5. BIODIVERSITY, ECOSYSTEM HEALTH AND INTEGRITY, THE BALANCE OF NATURE, AND TAUTOLOGY

The fifth problem Sagoff (2005) describes for the view that NNS cause environmental harm is that the very definitions of certain phenomena they are sometimes said to harm – biodiversity, ecosystem health and integrity, the balance of nature – are ill-defined and may even be construed in such a way that a claim of harm from NNS may be tautological. I partially agree. The definitions of ecosystem health and integrity, and the balance of nature, are value-laden and subjective (Simberloff, 1980; Simberloff, 1998; Parker et al., 1999), and claims that NNS damage them are indeed in danger of being tautological. That is, the very definition of "ecosystem integrity" or "ecosystem health" can, and sometimes does, entail absence of substantial populations of NNS. Similarly, the balance of nature is frequently claimed to be upset by introduced species, but just as "natural" is often problematically conceived by definition to exclude NNS, or at least NNS introduced by humans (see, e.g., Cronon, 1996; Burdick, 2005), so can a balanced nature easily be defined to exclude them.

Biodiversity is another matter. It has both broad and narrow technical meanings (US Congress Office of Technology Assessment, 1987). The broad technical meaning is diversity at three levels – genetic, species, and community or ecosystem. For want of means to measure genetic and community or ecosystem diversity (although rapid progress has been made recently on the genetic front), by default most scientists when discussing biodiversity in a technical context are referring to species diversity, and almost always to species diversity as expressed simply by species richness, the number of species. As discussed in the above section, "Biodiversity, species richness, and ecosystem function," NNS do affect species richness, both globally and locally; it is not tautological to say so. Neither is it tautological to say an NNS affects biodiversity when biodiversity is explicitly stated to mean native species richness, as by Sala et al. (2000). Somewhat more problematic is the contention that NNS affect native biodiversity, by which is meant native species richness, when "native" is implied but omitted as a modifier of "biodiversity" (e.g., Muller, 2004). At least in scientific writing, it is almost always possible to determine from context what is meant, but in publications for a lay audience this is sometimes not so clear.

The bigger problem in lay writing is that "biodiversity" has come to be an exploded metaphor for all of nature, no doubt because its connotations in this context include political, social, and even ethical values. It is lamentable that writing for a general audience sometimes simply states that NNS harm biodiversity, in this vague sense, particularly when explicit examples of harm are not given. However, the existence of imprecise writing of this sort in no way invalidates the many well-defined and verified cases of environmental harm caused by introduced species.

6. CONCLUSION

Verified impacts of introduced species on natural environments are legion, including myriad cases in which there is both scientific and public consensus that the impacts are harmful. Among such impacts are many extinctions of both populations and species, including continental species. The massive evidence of such harmful impacts is exactly why regulatory policies have been developed and why stronger regulations have increasingly been proposed (Miller and Fabian, 2004). For virtually any phenomenon that harms or threatens to harm natural ecosystems, even when the overwhelming majority of expert opinion agrees on the menace, there are always a few individuals who argue that the case is unproven and overblown, that further action is unwarranted for now. Global warming is an excellent example. This is exactly the role that Sagoff (1999, 2000, 2005) has taken on with respect to NNS. In the face of widespread scientific and public recognition that introduced species cause great environmental harm in many forms, he selectively and often incorrectly cites scientific literature to argue that we need more proof of impact to warrant action. Just as with global climate change, it would be cheaper and easier in the short term to say there is not scientific consensus and we should delay regulation. It would also be both incorrect to say the science is ambiguous and dangerous not to act.

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