POLICY PERSPECTIVE

Invasive Species: to eat or not to eat, that is the question

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Abstract

Managing invasive species is a current challenge for biodiversity conservation. A recurring recent suggestion is that by harvesting nonnatives for human consumption, people can control invasive populations. Even though humans may be able to control or eradicate certain populations of nonnative species by harvesting them as food sources, several caveats should be considered before starting these programs. A prominent problem is that creating a market engenders pressure to maintain that problematic species. Also, if the target species becomes an economic resource, people may try to recreate that market in previously uninvaded regions. Using invasive species as an economic resource may trigger the local community to protect these harmful species, to facilitate their incorporation into the local culture, and can generate severe management problems. As with other management programs, managers must know if the harvest actually reduces the target population. Mortality could produce a reduction in the population size or growth, or it could be compensatory, in which case removal of the harvested individuals would not affect population growth. However, in addition to possible control, there may be several benefits of this approach, including an opportunity for public outreach. Projects aiming at controlling invasives through human consumption should be carefully examined, as they may produce results opposite to those proposed.

Introduction

Different approaches are widely used to control invasive introduced species, including chemical application, mechanical or physical removal, and biological control (Simberloff 2001). An approach based on removal of individuals, harvesting and eating nonnatives, is occasionally proposed and is recently gaining in popularity (Franke 2007; Rosenthal 2011). The idea that human consumption can control nonnative populations accords with one of the most important hypotheses to explain invasion success, the enemy release hypothesis, which proposes that invasives thrive because of the lack or scarcity of enemies in the new range (Keane & Crawley 2002).

The idea of eating invasive species is not new. For example, eating invasive species (e.g., weeds) has been proposed previously for other reasons, including as a good food source given their ubiquity and abundance (Rapoport *et al.* 1995; Diaz-Betancourt *et al.* 1999). Many cookbooks focus solely on recipes for invasive species, like kudzu (Baldwin 1999; Reed 2002). Human consumption as a way to control invasive species is not a new idea either, and it has been applied several times in previous decades, for example, to target nutria (*Myocastor coypus*) in Louisiana, USA in the 1990s (Boudreaux Bodin 1998). However, the idea that by eating invasives, humans can significantly affect their populations has recently surged in popularity among government agencies, conservation groups, and the media (e.g., Barclay 2011; Minsky 2011; Rosenthal 2011; Vozella 2011). A few current examples include the Illinois Department of Natural Resources "Target Hunger Now!" campaign that seeks to feed the hungry and decrease nonnative Asian carp (*Hypophthalmichthys nobilis*) in state waterways (McCloud & Solano 2011), the U.S. National Oceanic and Atmospheric Administration's "Eat Lionfish" campaign that promotes consumption of the marine invader the lionfish (*Pterois volitans*) (NOAA 2011), and the Mid-Atlantic Exotic Pest and Plant Council's "Eat Those Invasives!!" initiative that suggests harvest

strategies and recipes for common invasive plants of the region (MAEPPC 2011). Many other invader recipes, all of which are proposed to help reduce their impacts, are currently advertised online and in print, for example, on the website *invasivore.org* or in the "Conservation through Gastronomy" cookbook (Franke 2007).

The notion that we can control species by eating them is based on the assumption that, as well-known voracious predators and owing to our huge and growing population size, we can control species' populations or even drive them to extinction (which can be analogous to a successful eradication program). The primary evidence in favor of gastronomic control is the many species humans have driven to extinction or near-collapse by overharvest. One such a collapse is the crash of the Atlantic cod (*Gadus morhua*), which the fishing industry overharvested decades ago; even under strict management the population has yet to recover fully (Murawski 2010). Other species at risk of extinction owing, in part, to current or past overharvest are American ginseng (*Panax quinquefolius*) (McGraw 2001), several palm species (for use of palm hearts as a food) (Johnson 1996), and the spiny-tailed iguana (*Ctenosaura bakeri*) of Honduras (Pasachnik *et al.* 2009). Examples of extinct species lost in large part from overharvest include moas in New Zealand (Holdaway & Jacomb 2000), the woolly mammoth (Nogués-Bravo *et al*. 2008), and the passenger pigeon (*Extopistes migratorius*) in North America (Halliday 1980).

Despite the fact that humans could potentially control or eradicate populations of nonnative species through gastronomy, several caveats should be considered. These programs could produce some unintended consequences, and they may produce results opposite to those proposed. These consequences could include the promotion of further invasions and the obstruction of future management plans (see below for a discussion of these points). It is important to remember that there are many differences between the species previously mentioned which, for several different reasons, were susceptible to human harvest pressure and the problematic species that are currently invading. For example, there is strong evidence that nonnative invasive species have higher growth rates, fewer pathogen and natural enemy attacks, and benefit more from disturbance than most native species (e.g., Keane & Crawley 2002; Klironomos 2002; Callaway *et al*. 2004; Hierro *et al*. 2006; Ramula *et al*. 2008), making invasives likely to be less susceptible to continuous harvest in comparison to their native counterparts. Here we analyze the pros and cons of attempting to control invasive species by eating them. We refrain from addressing particular harvest techniques, which are numerous and in some instances need further development for successful harvest programs (e.g., Thresher 1996; Yonekura *et al*. 2007), but we focus on the general issues of this approach. We discuss if, when, and how the approach of controlling nonnative species via gastronomy should be used.

Benefits

A number of benefits are associated with attempting to manage nonnative species by eating them. Further we describe the three that are especially important.

Increasing awareness of invasive species

Programs aiming to control invasions will educate their participants about the problems associated with invasive species (e.g., invasivore.org). This is particularly clear because people willing to work for these programs might be keen to understand more about invasive species and to share their knowledge with other members of their community. This type of outreach is analogous to other citizen-science programs in which nonscientists aid scientists in their research (Bonney *et al.* 2009) and also to some control programs organized by many local conservation organizations in which volunteers contribute to the mechanical removal of invasive species (Simberloff 2003). In addition, invasive harvest programs have the potential to attract interest from public sectors that are not typically focused on resolving environmental issues. Local chefs and food groups have been instrumental in raising awareness of edible invaders, but only after they learned about the use of invasive species through harvest programs (e.g., Food & Water Watch 2011; Vozella 2011; Walton 2011). Some individuals who initially participate in a harvest program for the food value may learn more about the impacts of nonnatives and eventually participate in "traditional" management programs not aimed at eating nonnatives. Outreach seems a clear, positive aspect of harvest programs.

Assisting in early detection and rapid response efforts

Early detection and rapid response (EDRR) initiatives have been proposed as a key technique for successful eradication of new invader populations. However, for EDRR to function, people must be able to identify species of concern correctly and there should be many observers frequently visiting a wide range of habitats. Programs educating people on using invasives as food could promote identification of invasive species to the nonscientific community and have the potential to facilitate EDRR, in analogous fashion to similar successes of citizen-science programs aimed at teaching about invasive species (Jordan

et al. 2011). Many websites couple identification keys with suggested recipes to insure accurate identification of the invader (IPANE 2011; MAIPC 2011). If more people are able to identify problematic invasives, it is more likely that they will successfully detect a range expansion or the arrival of invading species in a new region.

Boosting local economy

It is important to remember that some invasives are part of the local economy and incorporating them into their culinary culture may be an important source of local income. For example in Patagonia, a local delicacy is food based on hunting of nonnative red deer (*Cervus elaphus*), hare (*Lepus europaeus*), and salmonid fishes (*Salvelinus* sp., *Salmo* sp., and *Oncorhynchus mykiss*) (Lambertucci & Speziale 2011). In Hawaii, pigs (*Sus scrofa*) were first introduced by Polynesian settlers and contemporary feral populations are protected and managed by the state's wildlife agency, which has no clear intention of ever eradicating the species from all the islands owing to their hunting value (Fujimori 2003). The hunting benefit can be contrary to the main goal of the management programs (controlling invasive species), but pigs clearly confer an economic benefit. Many invasive species throughout the world positively affect the local economy, at least temporally, and this may be an important aspect to consider.

Problems, challenges, and possible unintended consequences

Besides the benefits that programs based on controlling species via gastronomy can have, a number of serious potential problems, challenges, and possible unintended consequences are associated with this approach. A few might even prove counterproductive for controlling nonnatives. Here we describe some of these potential pitfalls.

Failing to affect invader population size, expansion, or growth

To be successful, any management campaign using mechanical removal must insure the removal of enough individuals of vulnerable life history stages to cause a decline in population growth and size. Eating invader campaigns are no exception. A central aspect of many management plans should focus on insuring individuals removed are additive deaths (affecting population growth) and not simply a form of compensatory mortality (no effect on population growth; Crouse *et al*. 1987). Species-specific demographic matrix models and elasticity analyses are ideal for targeting the correct life stages and densities to cause population declines (Ramula *et al*. 2008). Because lack of demographic information on the target species is common in many management plans, this could also be problematic for gastronomical management.

Many campaigns to harvest plants do not kill the target species, but instead solicit removal of leaves (e.g., kudzu), fruit (e.g., eglantine, autumn olive, blackberry), or stems (Japanese knotweed), leaving behind reproductive parts that can later resprout or reseed. In a review of invasive plant demographic models, Ramula *et al*. (2008) found that on average a 60–95% reduction in growth or fecundity was necessary to change population growth rate from increasing to a decreasing for invasive plant species. This implies that "light" gastronomical harvest, such as removal of edible parts and not the entire individual, may be ineffective unless it is coupled with other management methods. Harvest of invasive animal populations might have higher success rates, because harvest nearly always removes entire individuals from the population. Yet, food harvest of entire individuals does not always guarantee success if the proper life stages are not harvested in large enough numbers from the population, which can be notably challenging (Thresher 1996; Kolar *et al*. 2010). It is also important to consider the spatial extent of the nonnative population. If the plan is to harvest specimens to supply local customers or restaurants, it may be impractical to collect in areas with low densities or in remote areas. Therefore, it may not be a reasonable strategy to control the species, if viable satellite populations in inaccessible areas remain unharvested.

The case of lionfish (*P. volitans*) exemplifies some of the challenges of using human consumption to control an invasive species. Lionfish have been released from aquaria along the Florida coast, and in the last 20 years, they have become a problematic species whose nonnative range has now expanded drastically, extending from the Florida Atlantic coast to the Gulf of Mexico and Caribbean Sea (Schofield 2009). The lionfish has been proposed recently as an ideal candidate to control by consumption. This possibility has been widely publicized in U.S. media, in part because of the tremendous potential detrimental effects of lionfish on local ecosystems and its culinary value (NOAA 2011; Rosenthal 2011; Walton 2011). However, research suggests that reducing invasive lionfish populations in large areas is not feasible in the long term because of their fast recovery after severe overfishing and their current widespread distribution (Barbour *et al*. 2011).

If the harvesting invader campaign is marketed as a way to decrease the population size and ecological impact of a species, a lack of success may create a backlash toward the overall goal of managing the target nonnative.

As with other failed attempts to control invasive species, local people may get frustrated after years of effort and may be convinced no methods exist to control the spread of nonnatives, which can hinder future management attempts.

Creating a market for a problematic species that, with time, will need to be maintained

The ultimate goal in most eating invader campaigns is to eat the target species out of existence, just as humans have done for many native species. However, once a species becomes a genuine economic resource, it could be even harder to encourage complete removal of the monetarily valuable species. What began as an attempt at eradication or control could emerge as a marketplace that demands a species be kept at levels at which harvest for commercial purposes is viable. Invasive species with high economic value tend to be protected (see below). Eliminating jobs or reducing the income of local residents who formerly earned a living by trapping, hunting, or raising nonnatives for food may trigger negative responses by the local citizens who value their current welfare more than they deplore a negative ecological effect of the invasive species.

There are many examples of how hard it can be to persuade the public to forgo purchasing or propagating invasive species that are a valuable source of income. This is the case even when species cause important deleterious problems to the environment. Some nonnative invasive plant species are popular commodities in forestry, horticulture, or traditional medicine industries. Forestry in the southern hemisphere is based on nonnative trees, for example, many pine species, and many of them are highly invasive (Simberloff *et al.* 2010). However, owing to their huge importance for regional economies, attempts to stop planting invasive trees are impractical (Richardson 1998). In North America, a major introduction pathway for invasive woody plant species is the horticulture industry (Reichard & Hamilton 2001), but because woody plants yield over $3 billion in annual horticultural nursery stock sales in the United States (over 82% of sales in this market) (USDA 2010), it is not trivial to convince the industry to cease selling profitable species, even if they are highly invasive. Single nonnative species can have great economic value and produce major clashes between environmental groups and the horticulture industry. In Connecticut, USA, the ornamental shrub Japanese barberry (*Berberis japonica*) is listed as an invasive species by the state's Invasive Plant Council but it has proven difficult to prevent its sale because it has an estimated annual crop value over $5 million (Lehrer *et al*. 2006). Although these examples are of invasive species not promoted for human consumption, they nevertheless shed light on the challenges on controlling species that generate economic benefits.

Some invasive animals are also integral components of hunting and fishing industries and are regularly used as food sources. Many nonnative game species, such as brown trout (*Salmo trutta*) in New Zealand (Veitch & Clout 2001) or red deer (*C. elaphus*) in Patagonia, are important to the hunting and fishing industries. These species are unlikely to be eradicated when pressure to maintain populations is high (Lambertucci & Speziale 2011).

Promoting further invasions

If a species becomes a genuine economic resource, this may trigger its spread. People living in areas where the species is not currently found may relocate invasive individuals in an attempt to imitate successful businesses in the invaded area. Illegal fish stocking is an international problem, with people introducing nonnative, invasive fish to supplement native fisheries (Johnson *et al.* 2009). An example of this is northern pike (*Esox lucius*), which is a common species in sport fishing. It was introduced illegally in Lake Davis, California, USA for fishing in the 1990s. Campaigns to control and eradicate the fish have been in place since its discovery given the large impact and devastating effect that this carnivorous fish has in the lake and the threat it poses to the native fisheries in California because Lake Davis empties into a larger watershed system (the Sacramento—San Joaquin delta system; Aguilar *et al*. 2005). After a successful program to eradicate the invasive northern pike, locals are believed to have reintroduced the species to promote fishing, which was an important source of income for the local economy (Elmendorf *et al.* 2005).

Harvesting may also promote further invasion by unintentional dispersal of propagules. This might be especially important when harvest is of viable parts of the specimens like seeds, bulbs, or living individuals. By increasing the number of people harvesting a species, we also increase movement of it, which may be problematic.

Promoting incorporation of invasives into local cultures

If the species becomes a desirable target, local people can make it impossible to eradicate or control because of cultural attachments to the species (Nuñez & Simberloff 2005). Examples abound of invasive species used as food source that are ingrained in local culture. In the Hawaiian Islands, controversy exists between conservationists and hunters over the control of wild boar, introduced

originally as a food source (Burdick 2006). Wild boar is a species with well-known drastic effects, given their ability to modify entire ecosystems (Nogueira *et al.* 2009). The native people of Hawaii have historical, strong ties with the species as a food source. Also, traditions and rituals associated with hunting wild specimens promote the boars' presence in Hawaiian forests and leave no culturally acceptable alternatives to boar hunting (e.g., purchase of pigs in grocery stores; Burdick 2006). Nonnative red deer (*C. elaphus*), salmonid fishes (*Salvelinus* sp., *Salmo* sp., and *O. mykiss*) and wild boar (*S. scrofa*) in Patagonia are problematic invasive species and also good examples of nonnative food sources that are now deeply rooted in the local culture. For example, food products derived from these species are marketed as typical Patagonian cuisine and restaurants label them as "traditional" dishes (Speziale *et al*. 2012).

Another example of a nonnative becoming a cultural icon is the wild horse (*Equus caballus*) of the American Southwest. Horses are nonnative, invasive species originally introduced by Spanish explorers to facilitate transport but are so deeply rooted in American culture and lore that control of their populations is nearly impossible, and eradication unthinkable. This nonnative species is so well loved that there are even federal laws to protect its herds. The Wild Free-Roaming Horses And Burros Act Of 1971 states "*That Congress finds and declares that wild free-roaming horses and burros are living symbols of the historic and pioneer spirit of the West; that they contribute to the diversity of life forms within the Nation and enrich the lives of the American people;. . .*" (Public Law 92–195). These examples show that once a species gains cultural value, it can be protected and treasured by the locals even if it is nonnative and invasive.

There may be a fine line between promoting consumption of a species and incorporating it into local culture. After a species becomes widely used it may become part of the culture, as has happened to many nonnative species (see Figures 1A and B). Also, when a species is appreciated or is a valued resource, it seems to matter little how much ecological damage it causes. Human pets, like cats (*Felis catus*) or dogs (*Canis familiaris*), demonstrate this point, because they can have huge ecological effects, but in many cases plans to control or extirpate populations are impractical. Therefore, by promoting the use of nonnative species, we may give them a market value and unintentionally promote their incorporation into the local culture, reducing the chance of success of future management programs.

There may be fundamental differences between species originally introduced as a food sources (e.g., fish, wild boar) and species introduced accidentally or for nonconsumptive reasons. People may be less likely to incorporate

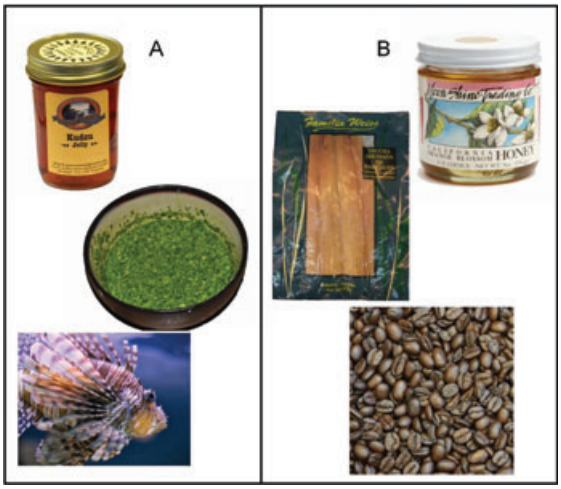

Figure 1 Photographs of invasive species products. Examples of products currently marketed for consumption, as a way to control their populations: (A) kudzu (*Pueraria montana*) jelly, garlic mustard (*Alliaria petiolata*) pesto, and lionfish (*Pteris volitans*). Examples of products currently considered a local delicacy, with no intention of using harvest as a means of controlling the populations: (B) honey (from *Apis melifera*) from California, smoked trout (*Oncorhynchus mykiss*) from Patagonia, and coffee (*Coffea indica*) from India. Photographs credits: R. Poplin, R. Vidal-Russell, and M. A. Nuñez.

into their culinary cultures nonnative species not introduced as food sources. Many of the examples of species that are now incorporated in local cultures (e.g., Figure 1B) were originally introduced for food production, so it can be expected that they became preferred food items. However, even foreign or novel food items can gain popularity and cultural staying power. Studies on food neophobia, the fear of new foods, tell us that there are ways to overcome people's reluctance to try new food items. Constant exposure to an item, association of the new food with positive attributes (e.g., conservation aids or good health), and ample advertisement can be effective in incorporating new food items (Shepherd & Raats 2006). For an invasive management program based on human consumption to work, many people must find the nonnative appealing enough to consume. Therefore a successful gastronomy program must entail incorporation of the species into people's food preferences, which if successful, would lead to the incorporation of the exotic into the local culture. This may not be the case for invasive species that are rare or found only in few locations owing to a recent introduction, but may be the case for species that are abundant and widespread.

A way to avoid the incorporation of a problematic species into a local culture may be based in how the species is marketed. A constant reminder to consumers and collectors that the goal is to decrease population

size or to eradicate the species because of environmental problems that they generate can be key to avoiding unintended consequences. If people are not reminded of the overall goal it may be easier for the species to be incorporated into the local culture, to the point of becoming a staple item on the menu of local restaurants (as with deer, fish, and wild boar in Patagonia).

Discussion: recipes for success

Eating invader campaigns have several benefits; primarily, they can increase public awareness of invasive species issues and potentially help detect new populations. Also, there is ample evidence that humans can reduce population sizes of many invasive species by eating them. This may be especially attainable when the population size is low, as in the case of recent nonnative species introductions. Thus, if many people decide to control a species by eating it, this may be more successful when the species is rare, at the early stages of an invasion, rather than when a species is very abundant, at later stages. Programs based on gastronomic use can also be good complements to other programs, such as volunteer programs on mechanical removal of invasive species, generating a stronger combined effect. However, despite the potential benefits, managers deciding to implement this type of project should be cautious, because these programs may have unintended negative consequences.

If managers aim to decrease an invader's population through harvest, one of the first steps should be to understand fully the demography of the species. Matrix population models provide an effective tool for targeting the appropriate life stage that will cause the largest decrease to a population's overall growth rate. These models have been used to direct management strategies, including selecting the appropriate life stage to target for management of invasive plants and animals (Ramula *et al.* 2008; Barbour *et al.* 2011). These same techniques should be employed to test how harvest of edible life stages will affect the target species' population growth rate.

How to market the target invasive species may be fundamental. It may be good to remind consumers and restaurants that the goal is to decrease population size of the species and not to make it a staple item on the menu. Otherwise it will not take too long for people to start managing for high populations, as has occurred in some regions with invasive species (Lambertucci & Speziale 2011). Also, an aspect that may be important to consider when presenting nonnatives as new items for human consumption is conservatism of human food habits. People are inherently conservative in food preferences and cuisine, and they have a general tendency to dislike new foods (Rozin & Vollmecke 1986; Shepherd & Raats 2006). This intrinsic conservatism of people's taste could be problematic because the target invasive species may not be preferred and it may be difficult to encourage consumption. This barrier may not be insurmountable (see above), but it is formidable. For species like cod that have been part of the culinary culture for centuries, it may be easier for humans to affect their population size through harvest. However, when species are foreign to the general public, like kudzu or nutria (also know as river rat), it might be harder to introduce them as food items.

Not promoting the cultural incorporation of the nonnatives species may be particularly hard to achieve. If a food item becomes locally attractive, a campaign to control its population to keep low numbers or to eradicate it may be controversial (Nuñez & Simberloff 2005). Management programs that aim to use nonnatives as food sources may want to focus on the beneficial outreach aspects, because they are likely to gain widespread attention. Also, not promising control or eradication success (especially without demographic models that support this outcome) seems to be especially important. Failed management campaigns can stoke citizen frustration with all nonnative control programs and may lead to the assumption that nothing should or can be done to control nonnative species (e.g., Davis *et al.* 2011).

A number of positive aspects are associated with the goal of using invasive species as a culinary resource. However, it is important to remember that sometimes doing nothing (do not eat them) may be better than promoting their incorporation into the local culture or creating a market that can be a problem for future management programs. Decisions to start or maintain a program based on human consumption of an invasive species as a way to control it should arise by carefully considering the potential benefits and problems that the program could produce.

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