2017

Evaluating Trophic Rewilding as a Conservation Technique

Aaron Sieve
Augustana College, Rock Island Illinois

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BIOL 464
Inquiry Paper
2/12/17

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On the surface, rewilding would seem to be a word that is simple to understand. The average person would easily be able to make up a definition. One example definition could be returning something to an earlier and more primal or natural state (Jørgensen 2015). This would be an accurate definition for its conservation use as well, but it does not encompass the specific methods that are used. Rewilding has been proposed as a technique to restore many degraded habitats and has already been implemented many times (Cornelissen et al. 2014, Hunter et al. 2013, Ripple and Beschta 2011, Smit et al. 2014, Van Klink et al. 2016). With even more rewilding projects proposed, an increasing number of people will be affected; therefore, it is critical to clarify the term (Sandom et al. 2013). The focus for this paper is to define specifically trophic rewilding, determine its efficacy as a conservation technique, and explore ways to lessen one of its key limitations.

Definitions of Rewilding

Conservationists have used the term "rewilding" to apply to slightly different methods for ecological restoration of a degraded area with the two main subcategories being Trophic Rewilding and Pleistocene Rewilding. It is important to highlight differences in the use of the term in order to maintain clarity.

Pleistocene Rewilding is a highly controversial subcategory of rewilding (Svenning et al. 2015). The goal of this type of rewilding is similar to other types that will be discussed, because it argues for the reintroduction of large vertebrates to degraded habitats in order to restore ecosystem function (Donlan et al 2005). Pleistocene Rewilding differs from others in its ultimate restoration goal and the kinds of species introduced. The ultimate goal of Pleistocene rewilding is to restore North American habitats to what they were before the arrival of humans, some 13,000 years ago (Donlan et al. 2005). The species proposed to be used in this rewilding project are Przewalski's horse, Bactrian camels, African cheetahs, Asian and African elephants, and lions (Donlan et al. 2005). Most other rewilding subcategories propose the introduction of species that are more closely related to those that have been more recently extirpated (Jørgensen 2015). An argument against Pleistocene Rewilding is that it will incur large costs and will not likely to be supported by the public due to the potential danger from large predators (Rubenstein et al. 2006). In addition, ecosystems present in North America have changed from 13,000 years ago, giving reintroduction of these species the great potential to become invasive and cause harm to existing native species (Rubenstein et al. 2006). A much simpler argument is that the current climate of Africa is much different than that of North America, so it is not likely that these species would survive upon reintroduction (Rubenstein et al. 2006). Many of the species proposed to be reintroduced are endangered, so it would be disastrous if these reintroduced species were to die. Pleistocene Rewilding is largely hypothetical at this point and is extremely controversial, which is why it will not be considered further in this paper.

Rewilding has also been used to refer to the replacement of extinct species with those from the same taxa (Jørgensen 2015). This method is used in both trophic and Pleistocene rewilding when the native keystone species has gone extinct. The use of species introduction as a method for habitat restoration has also been referred to as rewilding (Jørgensen 2015). Rewilding can also refer to a method of habitat restoration where land that was once used in agriculture is abandoned and allowed to passively return to a more natural state (Jørgensen 2015). These three definitions of rewilding are less widely used than that of trophic or Pleistocene rewilding, and will also not be discussed further.

The original use of the term “rewilding” referred to the conservation methods of the Wildlands Project in the US, which was founded to create conservation areas that excluded human use, and were connected through corridors (Jørgensen 2015). The main aim of this network of reserves is to protect keystone species, more specifically large carnivores, which need larger areas to roam as they search for prey (Soulé and Noss 1998). These goals are often shortened to the 3 C’s of “cores, corridors, and carnivores” (Soulé and Noss 1998). Usually, the restoration goal is to reach a level where the habitat functioned as it did at a point before such large predators were extirpated (Jørgensen 2015). The main argument for this type of rewilding is that large predators are necessary to maintain functioning ecosystems through means of trophic cascades, or top-down regulation of their prey (Soulé and Noss 1998). In many cases, this will limit the need for human regulation of population density of prey species in that ecosystem (Ripple and Beschta 2011). An additional argument is that humans have caused the decline of most predators through targeted killing, and so should feel obligated to bring them back (Soulé and Noss 1998). Other conservationists have expanded this definition of rewilding to include the reintroduction of other keystone species, such as large ungulates, in order to maintain the trophic levels of other species (Svenning et al. 2015). Both of these methods seek to re-establish ecosystem function through trophic cascades by keystone species, so they can be combined and referred to as trophic rewilding. Trophic rewilding is the sub-category of rewilding that I will focus on for the rest of this paper, as it seems to be the most prominent and effective mechanism for restoration.

Delving into Mechanics: Trophic Cascades, Keystone Species and Ecosystem Engineers

The ultimate goal of trophic rewilding is to return ecosystem function and self-regulation of a degraded area by reintroduction of extirpated keystone species (Svenning et al. 2015). According to rewilding literature, keystone species are those that impact their ecosystem more than would be expected through their interactions with other species in the area (Soulé and Noss 1998). It is proposed that this unequal effect on other species is possible through top-down regulation, also known as a trophic cascade (Svenning et al. 2015). Trophic cascades occur when an apex consumer's direct impact on another species is spread through the food web, thus shaping the ecosystem (Svenning et al. 2015).

To better understand the concept, one can think of a food web with several trophic levels: predators, herbivores, and autotrophs. Predators directly limit herbivore abundance by killing them, but also indirectly affect autotrophs by limiting the number of herbivores that can forage on them. Here we see an example of a trophic cascade whereby, through both indirect and direct interaction, an action by a species at a higher trophic level goes down the web influencing other lower trophic levels (Ripple et al. 2016). Predators are also known to affect prey behavior by causing their prey to avoid certain higher danger zones (Ripple et al. 2016). This analysis is not to say that ecosystems are not controlled through bottom-up regulation, such as competition for resources, but this effect is not the focus of trophic cascades (Ripple et al. 2016). At any rate, we can see the potential importance of reintroducing a keystone species back into a habitat where it has been extirpated. Such benefits of reintroducing a large predator could be seen in a reduction of the need for human management of prey and autotroph species (Ripple and Beschta 2011).

Besides herbivore regulation, keystone species in the form of large predators are also seen to maintain the density of other smaller predators, called mesopredators (Ripple et al. 2016).

This direct control on mesopredators allows the number and diversity of small prey, which the large predators do not eat, to increase (Ripple et al. 2016). Because of the top-down effects at multiple levels, this is another example of a trophic cascade. The importance of such a control mechanism is seen in Australia, where dingoes, a large predator, are targeted for lethal control in many areas (Wallach et al. 2008). Wallach et al. (2008) showed that where dingoes were absent, there were significantly less endangered yellow-footed rock wallaby because dingoes were important in controlling the population of foxes and cats, which are both mesopredators that feed on wallabies. Again, the benefit of rewilding is shown through the importance of maintaining each trophic level, and especially keystone species in an ecosystem.

Ecosystem engineers are another type of keystone species that are used in trophic rewilding projects to restore functioning ecological processes to an area (Sandom et al. 2013). An ecosystem engineer is any organism that indirectly affects other organisms by “creating, modifying, maintaining, or destroying” their environment (Byers et al. 2006). Removal of an ecosystem engineer will alter the resources and/or ecological function of a habitat. Reintroduction of an ecosystem engineer is a rewilding mechanism used to return balance to an ecosystem, often reducing the amount of human maintenance that is needed (Ripple and Beschta 2011). There are two types of ecosystem engineer— autogenic and allogenic. Autogenic engineers are organisms that change their environment through their own physical body (Jones et al. 1994). An example of this would be trees, not because they provide a home for other organisms but, because their presence alters hydrology, nutrient cycles, and even temperature of the habitat (Jones et al. 1994). An allogenic engineer is one that changes their environment by manipulating the environment around them (Jones et al. 1994). One prime example would be a beaver because they create pools in rivers through the building of dams (Jones et al. 1994).

Ecosystem engineers are keystone species because they impact many other species around them both directly and indirectly though the habitat that they have created.

In the context of restoration, ecosystem engineers are necessary to re-establish processes that have become defunct. When beginning a restoration project, it is important to start with the reintroduction of an ecosystem engineer because ecosystems that are the most highly regulated by biotic components within it are the most difficult to restore, this is known as the argument of alternative system states (Byers et al. 2016). Highly regulated systems are the most difficult to restore because the state of the environment can easily be changed to an alternate, less functioning state with the removal of one level of biotic control (Byers et al. 2016). It is often the case that when reintroductions begin with non-regulating native species, they are not able to survive because they cannot overcome the changes to the abiotic environment that occurred due to the removal of such controls (Byers et al 2016). Since ecosystem engineers function to manage biotic and abiotic processes, they can change the system back to the original state, allowing other native species a better chance at survival.

Review of Rewilding Cases

There is a significant amount of literature that suggests rewilding a degraded habitat with keystone species could be a beneficial method of restoration (Byers et al 2006, Jones et al. 1994, Ripple et al. 2016, Soulé and Noss 1998, Wallach et al. 2008). It is also important to ascertain the effectiveness of such a strategy from actual, real-world examples and experiments because there are many theories that seem to work on paper but have no merit in the real world. One example that is well-known in the field of conservation is the cane toad, which was introduced to

Australia to control pests but quickly became invasive and destructive to many native species (Shine 2010).

The Oostvaardersplassen in the Netherlands is Europe's oldest large scale rewilding project (Smit et al. 2014). This area was once agricultural land that was converted to a wildlife park in the 1970s (Smit et al. 2014). Research has shown that the historical landscape of much of Europe was woodland and pasture (Smit et al. 2014). During the 1980s and 1990s, Heck cattle, Konik horses, and red deer were introduced to the park as substitutes for extinct large ungulates to graze pastures and allow for re-establishment of trees to encourage this historic wood-pasture landscape (Cornelissen et al. 2014). The large herbivores in the Oostvaardersplassen are bottom-to-top regulated as there are no predators or annual culling. This lack of regulation has led to high population density in all three species (Smit et al. 2014).

There were several experiments ran in the Oostvaardersplassen to determine how grazing and ungulate density affects sapling establishment and density of other animals and plants. (Cornelissen et al 2014, Smit et al. 2014, Van Klink et al. 2016). Van Klink et al. (2016) found that while the exclusion of herbivores led to decreased biodiversity, edges of pastures showed increased plant and animal diversity over the more heavily-grazed center, meaning that ungulates may be more effective in smaller numbers. Cornelissen et al. (2014) found that large herbivores have a positive impact on the establishment of woody plants but only when the herbivores are at low densities. When saplings were planted in areas with no access, partial access, and full access to herbivores, Smit et al. (2014) found that after four years, no saplings survived in areas that the herbivores had full access, and they found a success rate of about 25% in areas where herbivores had partial access (Figure 1).

These studies all show that the herbivores in the Oostvaardersplassen all would contribute to species diversity and sapling recruitment at lower densities than were present. The relative failure of this rewilding experiment illustrates the importance of top-down control from a keystone species, usually a predator, in an ecosystem. In fact, one study proposed methods to control the densities of herbivores through fencing off certain areas, introduction of a predator, or culling (Smit et al. 2014).

In 1995, gray wolves were reintroduced to Yellowstone National Park in Wyoming after seventy years of their extinction from the area. Due to decreased predation during wolf extirpation, the Rocky Mountain elk population expanded rapidly which caused a decrease in woody plants on creek banks (Ripple and Beschta and 2011). An abundance of plants in riparian areas is necessary to prevent erosion of streambanks and maintain the quality of water (Beschta and Ripple 2016). Wolves were reintroduced to once again maintain the population of elk, thus triggering a trophic cascade and releasing riparian woody plants from such voracious grazing.

After wolf reintroduction, Beschta and Ripple (2016) compiled data on changes in riparian and upland plant height and density and compared them to wolf and elk population estimates for 20 years before and after wolf introduction into Yellowstone. These data were then compared to the climate, snow pack, and stream discharge to ensure that any changes recorded were not caused by environmental data instead of changes due to a trophic cascade (Beschta and Ripple 2016). This study found that after wolves were reintroduced, both riparian and upland woody plant density and height increased and the elk population had decreased with each year (Beschta and Ripple 2016; Figure 2). Air temperature, precipitation, snowfall, and snow pack were not significantly different for the twenty years before and after wolf introduction, meaning that the population changes could be more confidently attributed to the wolves (Beschta and

Ripple 2016). The authors concluded that the increased density of woody riparian plants was due to a wolf-induced trophic cascade that improved the ecosystem's function, as evidenced by the return of beavers to the area (Beschta and Ripple 2016).

In a similar experiment, Ripple and Beschta (2011) concluded that one possible mechanism for increased riparian plant recruitment in Yellowstone was the decrease in the elk population caused by consumption by wolves. In addition to this mechanism, they proposed that because elk have decreased the amount of time that they spend at higher-elevations and near streambanks, the change in elk behavior was due to the fear of predation (Ripple and Beschta 2011). The reasoning behind this assumption is that elk are more vulnerable at high altitudes during winter because of a higher volume of snow that makes them slower and that they are more vulnerable when drinking at the water's edge (Ripple and Beschta 2011). Both the behavior and density effects of wolves on the elk behavior have most likely combined to allow the increased height and density of riparian and upland plants. Studies on the reintroduction of wolves show that trophic rewilding can have a major positive impact on returning ecological function to a degraded environment (Ripple and Beschta 2011, Beschta and Ripple 2016). The difference in success between the Oostvaardersplassen and Yellowstone rewilding examples show the importance of having top-down control by an apex-species.

Wild boar reintroduction has been proposed for the Scottish Highlands at the Alladale Wilderness Reserve to restore cycles of ground disturbance to the landscape. The cycles of disturbance that the boars can create have impacts at other trophic levels and makes the boar an ecosystem engineer (Sandom et al. 2013). Bracken fern, although native to Scotland, has become invasive due to the decrease in disturbance regimes because its dense rhizome system allows bracken to effectively outcompete other native plants (Sandom et al. 2013). Wild boars engage in rooting behavior while foraging that breaks up the soil, potentially opening patches of ground where bracken has taken over to allow other native plants to re-populate the area (Sandom et al. 2013).

Sandom et al. (2013) proposed a study to test the possible effectiveness of a full or seasonal boar release to disturb bracken fern growth. The results of the experiment showed that boar were more actively foraging during the autumn and winter months and that they were more likely to be rooting rather than grazing during the autumn and winter months (Sandom et al 2013; Figure 3). The experimenters also found that most, deep rooting behavior took place on bracken fern (Sandom et al. 2013; Figure 4). Sandom et al. (2013) argued that an effective conservation strategy would be to release wild boar into the habitat during the autumn and winter when they were the most likely to disturb bracken through deep rooting. This study on wild boars shows the positive potential impact that rewilding a keystone species, such as an ecosystem engineer, may have on restoring ecological processes and reverting a habitat back to its original state.

Factors that Limit the Success of Rewilding

There are several factors that may limit the success of a rewilding program. In order to assess whether the benefits are greater than the costs for this method of restoration, it is important to see what can go wrong. The Oostvaardersplassen rewilding experiment showed that the lack of population control can cause issues because, in this case, the large population of cattle, deer, and horses led to overgrazing that kept pastures short but also decreased woody plant recruitment (Cornelissen et al. 2014, Smit et al. 2014, Van Klink et al. 2016). To understand the effectiveness of one possible remedy to this situation, three studies tested the use of fencing that excluded these animals from certain areas to observe the fence's effect on woody plant recruitment. These studies all found that areas with exclusion fencing and edges of habitats both had a limited amount of herbivores which increased the amount of woody plants (Cornelissen et al 2014, Smit et al. 2014, Van Klink et al. 2016). Smit et al. (2014) suggested that the reintroduction of a large predator would effectively decrease the density of large ungulates to a more sustainable level and noted that this is likely to occur because wolves and lynx are returning to much of Europe. Thus, it is possible to decrease the population density effects on a habitat and in fact such outcomes are usually the goal of rewilding models.

Another issue with implementing a rewilding model recognizes that many times not enough is known about trophic cascades to be effective at creating a rewilding model (Svenning et al. 2015). Rather than showcasing a real limitation on the model itself, this point highlights the need for more comprehensive experiments and research to be done on trophic cascades in certain habitats. Many conservationists are also worried that reintroduction of a species that has been extirpated from an area for a long period of time will not be effective because the ecosystem may have changed greatly, perhaps due to climate change (Svenning et al. 2015). Many proposed rewilding experiments introduce species that are not native to that environment, but are close replacements for species that went extinct, which may increase the risk that these species become invasive upon release into the habitat (Hunter et al. 2013). These concerns further the point that more research needs to be done on the impact of climate change, something important for almost every aspect of conservation. As with every proposed species introduction, species need to be selected carefully and a controlled experiment needs to be done before full release.

The most frequently stated and largest limitation of rewilding is negative human-wildlife conflicts (Svenning et al. 2015). Such concerns include the fear of depredation of livestock, crop-raiding, destruction of crops, attacks on humans, and the spread of disease to humans or livestock (Dickman 2010). However, the causes of conflict can be much more complex than just direct harm. People's perception of various human-animal conflict may be more influenced by social factors such as culture, expectations, and beliefs (Dickman 2010). This means that even in the absence of any human-animal conflict, people may still have a negative perception of the animal in question (Dickman 2010). The need to reduce this human-wildlife conflict and increase positive attitudes surrounding an introduced animal is immense, as it can cause major loss to human well-being and reduce support for conservation projects (Kansky et al. 2016). The prevalence of this issue is magnified by the number of people that are moving to areas where the potential for human contact with wild animals is increased. Roman (2016) argued that conservation programs must build relationships and involve stakeholders for projects to be successful. Supporting this argument is the fact that reintroductions of mammals are more likely to be successful if all stakeholders agree with management protocol (Crees et al. 2016). Therefore, it is extremely important to limit perceived human-animal conflict for any proposed rewilding plans to be effective.

Limiting Human-Animal Conflict

There are several methods to reduce the effects of human-wildlife conflict. These include payment for damage, lethal control, targeted feeding, fencing, and involvement of the community in planning of rewilding projects. Lethal control is an often-used method to both limit the population density of a damaging species, as well as remove the individuals that are doing the most harm (Dickman 2010). Geisser and Reyer (2004) compared the effectiveness of lethal control, targeted feeding, and fencing in limiting damage done by wild boars in Scotland.

Harvest damage and production of farms near boar habitat was compared in different areas that were managed by these different techniques and it was found that the hunting of boars was the only variable recognized to significantly decrease the amount of damage and population density in the wild boar population (Geisser and Reyer 2004). We can see that hunting can be effective in decreasing the amount of human-animal conflict by reducing the amount of animals that can cause the conflict.

However, it is important to note that the lethal control may have trade-offs in some species of animals. Although culling of wolves can improve public acceptance, it is hypothesized that the hunting of wolves can also influence wolf behavior and decrease their effectiveness as an apex predator (Ordiz et al. 2013). The argument is that when predators are hunted they will avoid areas where they are vulnerable, allowing their prey to use these same areas for protection (Ordiz et al. 2013). In addition, a smaller population of predators could limit their ability to reduce densities of their prey (Ordiz et al. 2013). Culling of predators can also affect pack social dynamics which control reproduction and range size, so it may have a counterintuitive affect where predator population size and range increase the more these animals are killed (Wallach et al. 2017). Wallach et al. found that following the prohibition of culling of dingoes, predation decreased as pack social stability increased and population size stabilized (2017). Lethal control may be effective in reducing human-wildlife conflicts, but it may also conflict with the conservation goals of many rewilding projects.

Another proposed method to limit human-wildlife conflict is targeted feeding. Targeted feeding could mean that extra food is supplied during shortage (supplementary feeding), or food is supplied to lure animals away from vulnerable plants, livestock, or human civilization (diversionary feeding; Milner et al. 2014). Geisser and Reyer (2004) found that targeted feeding of boars had no significant impact on the amount of crop raiding behavior. Milner et al. (2014) reviewed studies that monitored the effectiveness of diversionary or supplementary targeted feeding and examined the unintended effects of these programs. The results were unclear whether targeted feeding actually prevented the amount of damage to crops because, out of sixteen studies, six found that feeding reduced crop damage and four reported increased crop damage (Milner et al. 2014). One unintentional impact of feeding was that the supplementary feeding may increase the population size of ungulates, thus increasing the chance that crops will be damaged in the future (Milner et al. 2014). Targeted feeding may or may not be an effective method to limit human-wildlife conflict as it may depend on the environment, species, and human landscape in question.

Exclusionary fencing is another method used to reduce human-wildlife conflict. Fences are used to reduce harm to animals by people, keep large animals in protected areas, and to prevent crop and livestock raiding (Hayward and Kerley 2008). There are two types of fences, physical fences and metaphorical fences. Metaphorical fences are not physically there, but work the same way as a physical fence (Hayward and Kerley 2008). Examples of metaphorical fences are guard dogs and barriers of an unpleasant sound or scent. The type of fence that would work the best or whether any fence would work at all depends on the species to which it is being applied (Hayward and Kerley 2008). For example, from the earlier study on wild boars in Scotland, fencing did not significantly reduce damage to crops (Geisser and Reyer 2004).

Unfortunately, there may be some negative conservation implications that are caused by fences. Fences may restrict some species' migration routes and prevent species dispersion (Geisser and Reyer 2004). Both of these factors may decrease the species fitness due to increased inbreeding (Geisser and Reyer 2004). Fencing may even limit access to water which can decrease rates of survival in that population (Geisser and Reyer 2004). Some management issues that may arise are that fences need to be checked, and they can be costly to build and maintain (Geisser and Reyer 2004). Fences may be beneficial to decrease human-animal conflicts in some species, but their potential conservation and financial costs need to be weighed.

A final method to decrease human-wildlife conflict would be for managers of rewilding projects to work with locals to increase their tolerance to interactions with reintroduced species. One way to do this is to pay farmers and ranchers for any damage that is done to their property. Although one study showed that mitigation measures may have low accuracy in increasing positive attitudes towards human-wildlife conflict (Kansky and Knight 2014). Another proposed method that would work to increase the tolerance of stakeholders to wildlife interaction would be through working with the public from the start of the proposed reintroduction to understand what they feel would be an appropriate way to manage the animals (Kansky et al. 2016). This method may be critical in reducing conflict that is made through indirect social causes rather than the direct damage from the animal. There is little research done in this area of conservation but it is interesting to include with this debate because humans cannot be ignored when thinking about conservation programs and its goals. There are many ways to manage conflict between humans and wildlife, but there is no one correct way to do so for any place or species. Therefore, it is important to understand the viewpoints of stakeholders when deciding on any management strategy.

Study Proposal

Full reintroduction or seasonal release of wild boar into the Scottish Highlands may be a beneficial restoration technique for removal of bracken fern (Sandom et al. 2013). Rewilding an ecosystem engineer, such as the wild boar, will impact many other species and the ecosystem itself in a positive way by creating ecosystem processes that had disappeared (Beyers et al. 2006). However, if wild boars are released into the Alladale Wilderness Reserve, there is a potential for human-wildlife conflict because the boars may root in nearby agricultural fields (Geisser and Reyer 2004). Meng et al. (2009) found that wild boar can transmit diseases, such as swine fever, to livestock. It is important for managers in this situation to determine potential reactions to rewilding because this can determine the support that the project will receive later on and also help to anticipate any conflict that may be seen in the future. In order to effectively do this, it is important for all stakeholders to be involved to limit the amount of negative attitude towards boars that are due to social perceptions rather than actual activities of the boar (Kansky et al. 2016). Although boar reintroduction has been proposed for quite some time, no study has been done to assess whether the public would view it favorably. Therefore, it is essential that perceptions be assessed so potential strategies to increase support can be implemented, if necessary.

The following study design is adapted from research by Reading and Kellert (1991) that examined the knowledge, attitudes, and opinions of ranchers towards a proposed reintroduction site of black-footed ferrets and prairie dogs in Montana. This study was chosen because the authors incorporated questions about participant social beliefs that may cause dissent to reintroduction, in addition to participant's general beliefs about the animals being reintroduced (Reading and Kellert 1991). Social and political beliefs have shown to be extremely important in forming an individual's perception of human-wildlife conflict, for example, someone who believes that the government will use the boars as an excuse to manage their behavior are more likely to think negatively of the release of this animal (Kansky et al. 2016).

The proposed study features a survey of a sample of people associated with the associated area that investigates the participant’s attitudes and perceptions about wild boar. The sample will include 5,090 randomly-selected participants. The potential participants who are sent the survey will include 1,210 residents of Sutherland County (which contains the proposed reintroduction site), 1,285 residents of Glasgow (the most populous city in Scotland), 1,285 farmers throughout Scotland, 1,285 members of Scottish-based conservation organizations, and all 26 owners of agricultural lands surrounding the Alladale Wilderness Reserve. The sample sizes were calculated anticipating a 30% survey return rate at a 95% confidence level and a 5% margin of error (Kaplowitz et al. 2004). To calculate this, the populations of Glasgow (606,340) and Sutherland (6,071) were taken from census data (Glasgow…2016, Highland…2013). The number of farmers in Scotland was estimated from data from the National Farmer’s Union Scotland (65,000; Farming…2017). The sample size for conservationists that will be surveyed was matched to the other sample sizes for consistency.

These sampling groups were selected in order to gain further insight into local responses. It is not only important to understand the viewpoint of those that have land directly touching the Alladale Wildlife Reserve, but also, those in Sutherland county who may be impacted as well, through visits to the Reserve, an interest in conservation, or through a potential rise in food prices if boars damage nearby crops or spread disease to livestock. The attitudes of local farmers and Sutherland residents will be compared to those of farmers not specifically impacted by the reintroduction and people in the more urban environment of Glasgow to understand how location and way of life may impact responses. Finally, it is critical to understand how local views may differ from conservationists, who may be more likely to understand the importance of rewilding wild boars as a means for reducing an invasive species.

The participants will be selected through the use of the survey company Survey Sampling International (https://www.surveysampling.com). Farmers will be randomly chosen from a list provided by the National Farmer's Union Scotland. Members of conservation groups will be chosen at random from membership lists provided by the Scottish Wildlife Trust, the Caledonian Partnership, the John Muir Trust, Reforesting Scotland and the Scottish Wildland Group.

Though the survey itself will be online, a letter will be sent to the randomly selected individuals that will explain the purpose of the study and provide the website address of the survey. A reminder postcard will be mailed to those who did not partake in the survey after two-weeks and again after one month in order to encourage participation. Meanwhile, the survey of farmers surrounding the Alladale Wilderness Reserve will be handed out door to door to encourage a higher participation rate (Holbrook et al. 2003).

The survey itself will consist of attitude and opinion questions that will be assessed on a five-point Likert scale (strongly disagree, moderately disagree, neither agree nor disagree, moderately agree, and strongly agree). Six attitude scales (negativistic, libertarian/dominionistic, utilitarian, moralistic, humanistic, and naturalistic/ecologistic) from Reading and Kellert (1991) will be assessed and the definition of each attitude scale is presented in Table 1. Five to nine questions pertaining to similar basic attitudes towards boars will be asked to assess each scale. The scale reliability will be tested using Cronbach's Coefficient Alpha (Reading and Kellert 1991). This will measure how closely related the set of questions are for each scale.

Pearson chi-squared values will then be used to assess whether differences among the attitude questions are significant (Reading and Kellert 1991). The variation in specific group's perceptions of wild boar reintroduction will be assessed using multiple and step-wise regressions (Reading and Kellert 1991). Regression analysis is used to estimate relationships between the two variables. Next, the variance between the groups and the Tukey test will be used to calculate and compare the means of paired scale scores (Reading and Kellert 1991).

One hypothesis is that the data will show that a majority of both categories of farmers will have more negative responses to the reintroduction of wild boar than all other subgroups of respondents because they will fear potential damage to fields or disease exposure to livestock. Nilsen et al. (2007) studied rural and urban attitudes towards the reintroduction of wolves in Scotland and found that Scottish farmers had more negative responses than urban respondents, but 43% favored their reintroduction, so responses may not be completely negative. It is also expected that farmers will score highest in the negativistic, libertarian/dominionistic, and utilitarian attitude scales than the moralistic, humanistic, and naturalist/ecologistic attitude scales. This expectation is hypothesized because farmers rely on their land and livestock for their livelihood, so they will be more likely to want to prevent boars from entering their property in any way possible. The desire of farmers to control their properties potentially increases the chance that they will be resistant to government regulations (Reading and Kellert 1991). And finally, members of conservation groups are expected to have the most positive attitude towards rewilding wild boar because they are more likely to understand the importance of invasive species management.

Although analysis of this survey may provide a good idea of the general attitudes towards wild boar reintroduction, these attitudes may change quickly once boars are actually released into the Alladale Wildlife Reserve. It is most likely that attitudes towards boars will become more negative as more people interact with them. A study on the rewilding of wolves in Yellowstone National Park indicated that the more often that people encountered wolves, the more they had negative experiences with them, causing overall attitudes towards wolves to decline (Williams et al. 2002). Interestingly enough, positive experiences are seen to have less of a significant impact on improving attitudes towards wolves (Williams et al. 2002). It is possible though that if boars are only partially released during winter months, when they are less likely to impact crop yields, that locals will have fairly positive attitudes towards rewilding with boars. This positive response may be even more likely if boars are able to restore ecosystem function. It may be that no study would be able to accurately predict how public opinion will change on the advent of release, so continued surveying of the public opinion post-release will be necessary for conservationists to make fully-informed management decisions.

Rewilding can be an effective restoration mechanism in certain situations but its limitations, especially human-wildlife conflict, must be managed carefully to prevent failure. Rewilding can be effective because it reintroduces a keystone species to a degraded area that causes a trophic cascade that both directly and indirectly impact other species at lower trophic levels. Data show that keystone species may be necessary to revert the negatively altered states of damaged ecosystems back to the original functioning state (Byers et al. 2016). Restoration projects that have used a rewilding model have been mostly successful. However, like with the large herbivores in the Oostvaardersplassen, if the population density is not maintained at appropriate levels through top-down regulation, rewilding will not be as effective (Cornelissen et al. 2014). Other limitations to rewilding are the potential for long extirpated species or taxon replacements to become invasive. And finally, there is a potential for human-wildlife conflict because species that are reintroduced are usually large and may harm crops or domesticated animals. Ways to counter these human-wildlife conflicts are through fencing, feeding, lethal control, and changing the attitudes of those that are most likely to encounter the species (Hayward and Kerley 2008, Milner et al. 2014, Geisser and Reyer 2004). In order to make perception of the species used in rewilding more positive, the current attitudes toward their reintroduction must be assessed. It is also important for the public to know the purpose of rewilding and for conservationists to understand public perceptions of such programs, especially as the amount of rewilding programs increase.

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Supplemental Information

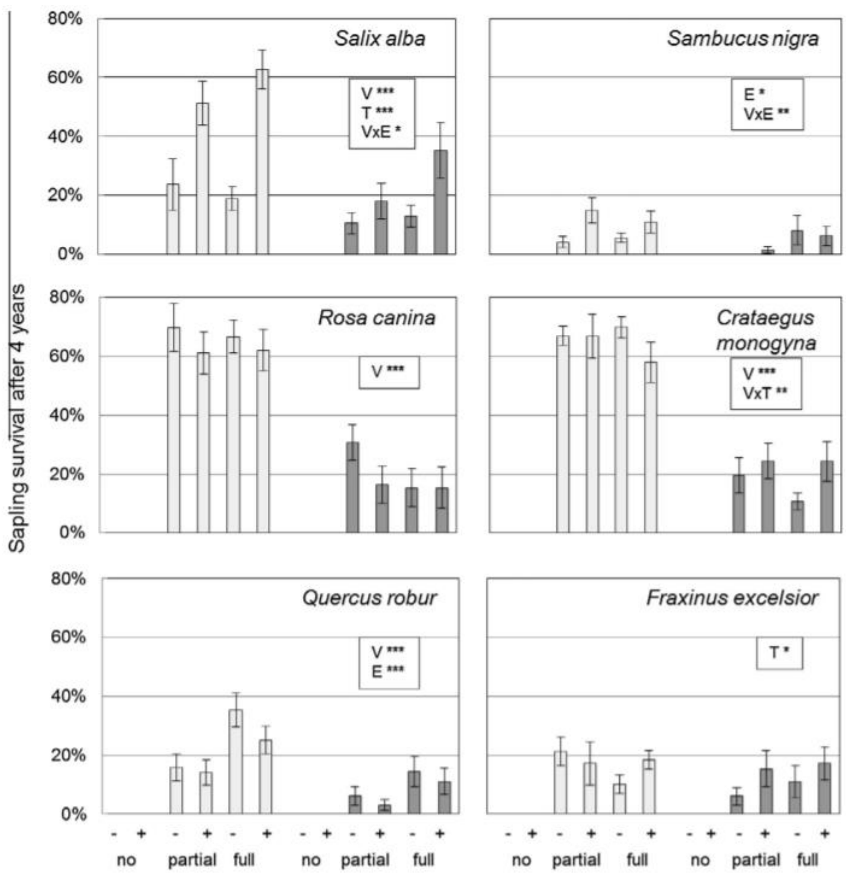

Fig. 2. Sapling survival (means ± 1 se) of the six woody species after four years in lawn (light bars) and rough (dark bars), in the three exclosure types (no, partial and full), with (+) and without (−) soil tillage. Indicated are significant variables and interactions of: vegetation type (V), exclosure type (E), soil tillage (T). $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

Figure 1. Oostvaardersplassen sapling survival after four years in three enclosure types. No saplings survived in areas that the herbivores had full access, whereas enclosure type was only significant for *Quercus robur.* Vegetation type, whether it was in the rough (dark bars) or lawn (light bars) also had a significant impact on sapling growth (Figure 2 of Smit et al. 2015).

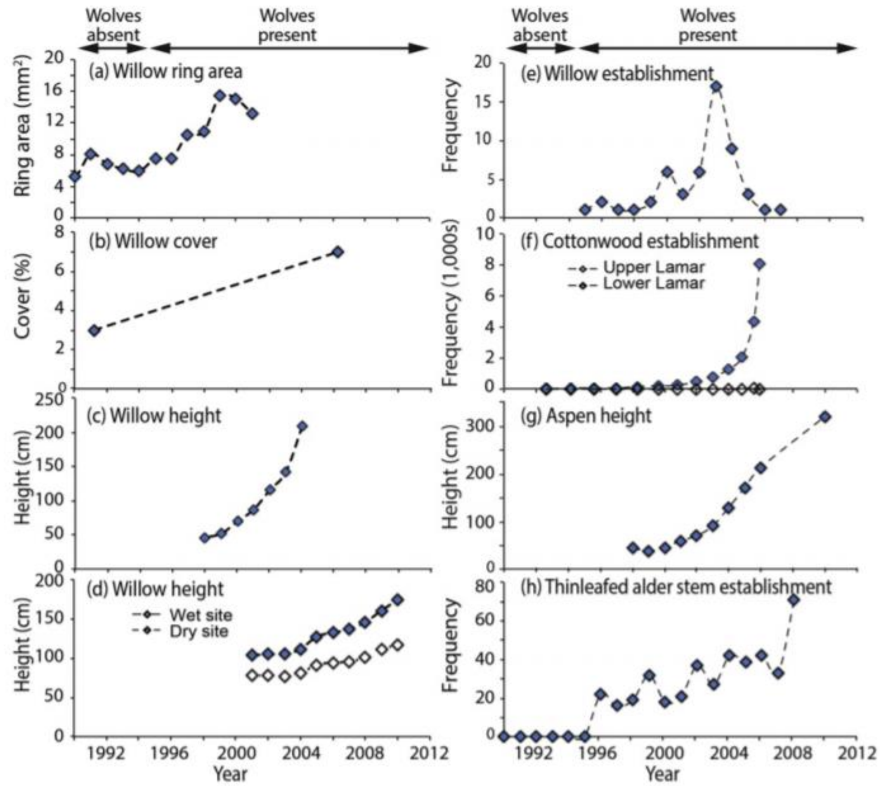

Fig. 3. Temporal changes of deciduous woody plants in Yellowstone's northern range riparian areas since 1990: (a) willow ring-area annual increment, (b) willow cover, (c, d) willow height, (e) willow stem establishment, (f) cottonwood establishment, (g) aspen height, and (h) thinleaf alder stem establishment; timing of studies vary. Adapted from: (a) Beyer et al. (2007), $n = 18$ study sites; (b) Baril et al. (2011), $n = 7$; (c) Beschta and Ripple, (2007a), $n = 3$; (d) Marshall et al. (2013), $n = 4$; (e) Marshall et al. (2014), $n = 17$; (f) Beschta and Ripple, (2014), $n = 2$; (g) Ripple and Beschta, (2012), $n = 4$; and (h) Ripple et al. (2015), $n = 6$.

Figure 2. Change in riparian woody plant in Yellowstone after wolf reintroduction from 1992 to 2012. Riparian woody plant density and height generally increased over the 10-year period (Figure 3 of Beschta and Ripple 2016).

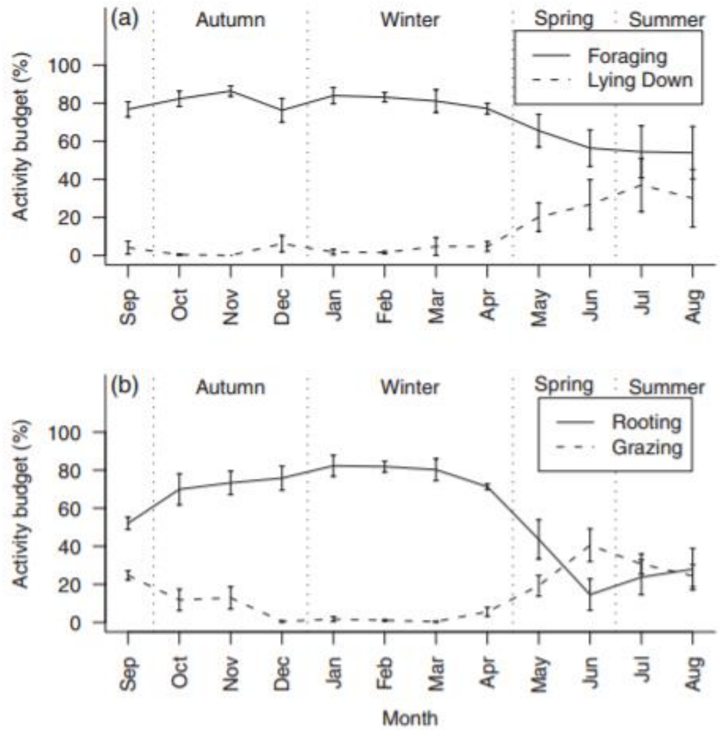

Figure 2. (a) Monthly variation in activity budget of lying down versus foraging ($n = 4$, mean, SE). (b) Monthly variation in foraging activity budget of grazing and rooting behavior (mean $\pm$ SE, $n = 4$).

Figure 3. Wild boar monthly budget of actvity (a) and foraging behavior (b) during release in Scottish Highlands. Boars are seen to be more active and partake in rooting behaviors more frequently during the winter and autumn but were less active and more likely to graze during the spring and summer (Figure 2 of Sandom et al. 2013).

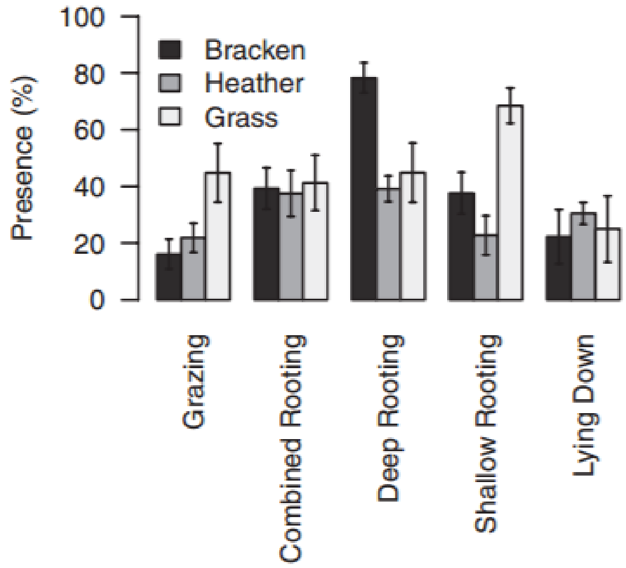

Figure 3. Proportion of time a particular vegetation type was present when a specific behavior was performed (mean ± SE, $n = 5$).

Figure 4. Wild boar proportion of time in different vegetation while preforming a certain behavior during release in the Scottish Highlands. Boar are most likely to graze in grass, deep root in bracken, and shallow root in grass, whereas vegetation type was not significant for combined rooting and lying down (Figure 3 of Sandom et al. 2013).

Table 1. Black-footed ferret/prairie dog attitude scale definitions.

Attitude Scale	*Definition*	*Cronbach's α**
Negativistic	Strong dislike or indifference towards black-footed ferrets and prairie dogs and their conservation	0.878
Libertarian/ Dominionistic	Strong interest in individual rights and freedoms and in the mastery, control, and domination of wildlife	0.878
Utilitarian	Strong support for the direct utilization of wildlife and subordination of wildlife habitat for human use	0.887
Moralistic	Strong concern for the possible infliction of cruelty, harm, and exploitation of black-footed ferrets and prairie dogs	0.882
Humanistic	Strong emotional attachment to, and support for the existence value of, black-footed ferrets and prairie dogs	0.876
Naturalistic/ Ecologistic	Strong interest in direct outdoor recreational contact with black-footed ferrets and prairie dogs and in their ecological value	0.882

** Cronbach's α is a measure of the scale's internal consistency. Interpretation is similar to that for a correlation coefficient ranging from 0 to 1.*

Table 1. Attitude scale definitions for black-footed ferret and prairie dog reintroduction. Replace "black-footed ferret and prairie dogs" with "wild boar" to increase relevance to this proposed study (Table 1 of Reading and Kellert 1993).