An investigation of the connection between the number of Invasive Alien Plant Species and rates of tourism within US National Parks

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Abstract

A consequence of globalization has been the Earth becoming a highly interconnected network of ecosystems. Humans have and are impacting the world in unprecedented and alarming ways – no area globally is free from our influence, and the consequences of these impacts are still unfolding. One such example is the spread of invasive alien species, where non-native species are introduced and become established in regions outside their natural limits. Tourism poses a massive threat; it is an efficient medium through which the ecosystem disturbance of globalization can occur. To test the effects of tourism on biodiversity, I set out to determine if there was a correlation between the number of visitors to US National Parks, and the respective numbers of invasive alien species present using data from the National Park Services website. While the results suggest that there isn't a connection between the two, they also highlight the need for more efficient management and sampling to truly understand the effect that individuals can have on ecosystems. The full impact of human activity is yet to be determined and this paper highlights yet another

Introduction

Invasive species can be regarded as a global problem that threaten a host of aspects within an ecosystem (Ricciardi, 2013). With an ongoing trend in globalization, the number of invasive species is increasing in a variety of different ecosystems – with increases in global trade tying strongly to the global distribution of these non-native species (Ricciardi, 2013) (Wesphal, et al., 2008). Broadly speaking, *non-native* species encompasses any species outside of its known historic range (Ricciardi, 2013). In a minority of cases these may become invasive, growing aggressively in numbers and potentially negatively impacting ecosystems.

An awareness of National Parks, as areas of preserved nature, and the impacts of invasive species has been known for nearly a century. In 1933 it was suggested that alien animals posed a significant threat to the preservation of national parks (Wright, et al., 1933). Given the high volumes of tourism and the international nature of these crowds, National Parks are increasingly at threat by non-native species invasions. Despite this is seems that there has been

limited research on human-mediated dispersal in national parks and the activities therein (Pickering & Mount, 2010). Given this, my intention setting out was to assess whether there is a correlation between the number of tourists in National Parks and the numbers of invasive species.

It seems like this should be the case as tourist activity would be one of the only ways in which *non-native* species might work their way into the parks. I have limited my study to invasive plant species, as this is the most straightforward to attribute to human activity – animals may migrate or be forced into national parks through other indirect means, additionally they are more difficult to sample or account for (many are cryptic or small, and the parks, on the whole, are huge). Plant species are often the focus of land management within protected areas, so are well documented by National Parks (Miller, et al., 2020) hence there is more information on them. The US National Park Service also provides useful data on tourist stats for decades, as well as invasive species information (DOI US Department of the Interior, 2021) both of which I used to perform my analyses.

Methods

To assess the effect of tourism on invasive species I found data on the National Park Service (NPS) website (DOI US Department of the Interior, 2021) for the number of visitors in parks from 2015 to 2020. Since the top 10 parks varied, I found data over the six-year period for any park in the top 10. This gave 12 results overall, however, two of these parks (Grand Teton and Acadia National Park) lacked any precise data on invasive species so were omitted.

I worked out the average of each of the national parks' visitors over the six-year period and plotted this into Table 1. Then on the NPS website, and other similar websites (Calflora, 2021) (Univeristy of Georgia Center for Invasive Species and Ecosystem Health; National Park Service , 2018) (Frakes, 2018) for individual parks, I obtained data on the number of invasive plant species corresponding to each park. I added all of this to Table 1 to collate the various details of the parks. Using this I then constructed Figs. 1 and 2. Fig. 1 shows the average visitors over the six-year period plotted against the number of invasive species. Following this, I considered the possible confounding variables that were interfering with the comparison. First, the parks are all different sizes – I added this to Table 1 and then elected to make a relative comparison of number of invasive species per km^2 of park. Seven of the values were between 0.02 and 0.04, one (Joshua Tree) was below this range and two (Olympic and Cuyahoga National Park) were above quite significantly. These numbers show that for the most part there hasn't been great variation in the number of

invasive species per unit area. Further analyses of the sites could be made to ascertain the differences or similarities in the number of invasive species. Finally I also plotted the data for area in km^2 against the values for invasive species to determine whether there was a trend in these values, this is shown in Fig. 2. Following this I searched on google scholar for more information on tourism, national parks, and invasive species trends across the US. This led to the conclusions reached in the discussion section.

Results

Fig. 1 shows the first set of results from the analysis: the number of alien species per park plotted against the number of visitors as an average of the last 6 years. This showed no discernible correlation, suggesting there is no direct trend between the two leading us to accept the null hypothesis that there is no trend. Additionally, from Table 1, we can see that the number of tourists annually is not directly correlated with the number of invasive species. This leads us to accept the null hypothesis that there is no relation. The range of visitors was from just over 2 million, all the way up to 11 million in the Great Smoky Mountains National Park, in Tennessee – a subrange of the Appalachian Mountain range. Despite having such a large number of visitors, this park was only 6^{th} largest of the parks assessed. Its high visitor frequency could relate to the number of visitors that hike the Appalachian trail from Springer Mountain Georgia to Mount Katahdin in Maine. Great Smoky Mountain National Park was the only one of the parks assessed that was a part of the Appalachian trail, the rest are more isolated. Apart from Cuyahoga National Park in Ohio and the Great Smoky Mountain National Park, the rest of the parks are #situated on the western side of the US.

Fig. 2 shows invasive species versus park size and does indicate a trend. This trend is that the number of invasive species increases with the size of the park in a predictable way with few discrepancies. The interesting fact about these discrepancies is that they were both parks with relative values for invasive species/km^2 outside of the general range (Olympic and Joshua Tree). Park area ranged from 131km^2 (Cuyahoga)to 11300km^2 (Yellowstone). Unlike the values for visitors there is a more even spread for the area of the national parks across the range. Three parks had within the 2 million range of visitors, and 4 parks had within the 4 million range – both of these facts are relevant when it comes to drawing reliable conclusions from the data. While there does seem to be some sort of log/lag trend in Fig. 2, we ought to be cautious about arguing for a direct trend, given the small sample size. But that being said the increasing number of alien species

with increasing area is in keeping with the theory that the number of species ought to increase with sampling area.

Discussions and Conclusions

There are several other factors to consider. First is how many of these tourists per park are international or come from areas outside of what would be considered the same, or similar ecosystems to the National parks themselves. For the species to be considered alien or invasive, it would have to be foreign to the foodweb, meaning that National Parks attracting a more international crowd are more at risk.

Secondly, it depends on the structure or layout of the national park. For instance, there has been shown to be a positive association between alien species richness and the length of the trail systems (Stohlgren, et al., 2013). This is not necessarily expressed in the value of the park area – a park with extensive trails may be much smaller than a park with sparser trails – it depends on the layout.

Thirdly, there are a variety of activities that occur within a national park. Some of the parks may not have a strong leaning towards tourist activities whilst other may. Pickering & Mount in 2009 studied the effect of human mediated dispersal of alien species through indirect means such as on clothing, vehicles, and horses. These obviously vary across parks depending on what is offered, whether transport vectors are restricted, and whether activities such as horse or donkey riding are offered. While they showed that there is data to suggest that horse dung, and seeds on clothing, cars, and mountain-bikes can disperse alien species within parks, they also conclude that more data and screening is required to reach stronger conclusions.

Fourthly, in comparing visitors across US National Parks, there is an assumption that the management techniques are similar or the same in all regions. However, monitoring and management programs are often hurriedly planned and implemented as well as insufficiently funded (Fancy & Bennetts, 2012). The management strategies across these parks likely vary greatly. An indication of this could be found in the income parks bring in. While I do not have evidence of this, it seems reasonable to suggest that parks earning more money are likely to be the ones with the funding to research and carry out more tailored or targeted ecological management programs. The relevance of this is that in those parks with better management one would expect to find fewer invasive alien species due to more effective screening and weed removal practices, as well as better monitoring of tourists entering the park to prevent their bringing alien species into

the park.

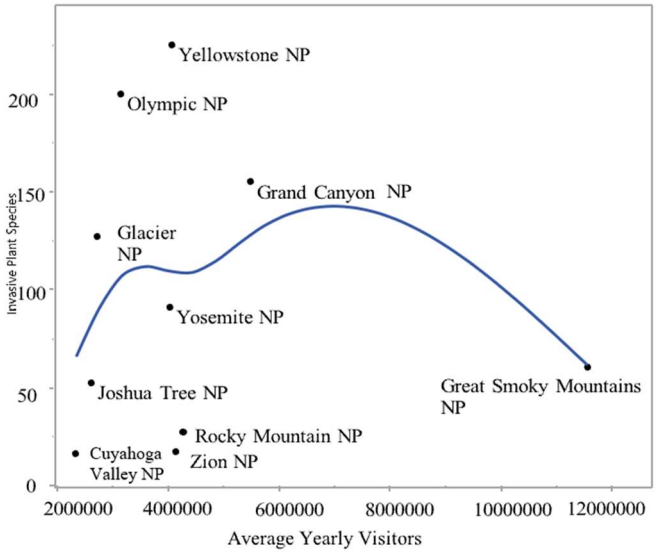
Fifthly, as alluded to in the results about the Great Smoky Mountain National Park's connection to the Appalachian trail, and a possible connection to my second and third points above, these parks are not congruous in their roles, locations, or what they have to offer. A concrete example of this is those parks related to the Appalachian trail, which, while it may have far more visitors, may attract a less international crowd. Further the interconnected nature of this Trail may allow a buffering effect to occur and protect the ecosystems from invasive flora or fauna through its biodiversity. The assumption that the ascription of National Park picks out something that makes these ecosystems similar is to ignore the human component in deciding what ought to be protected – some of these are isolated areas of beauty, others are greatly disturbed by human activity, and some further are relics of history.

Finally, another unknown effect within parks is that of trophic cascades. For instance, tri-trophic cascades have occurred in Olympic, Yosemite, Yellowstone, and Zion National Park of the parks studied (Beschta & Ripple, 2009). The loss of top predators, or their adopting of cryptic behaviour can have disproportionate top-down effects on the ecosystem. This may make the Park as a whole more, or less suceptible to alien species invasion. For example, in Yellowstone in the 1900s, the extirpation of wolves resulted in the intensive predation of seedlings by the elk, no longer regulated by wolves (Beschta & Ripple, 2009). This sort of effect may make it more difficult for alien species to establish due to predation, or open up new niches for their formation of a self-sustaining population.

It is difficult to assign one factor of National Parks as correlating with the occurrence of invasive alien species. But the conclusion here is that there is a desperate need to quantify, monitor, and manage National Parks effectively to prevent, as much as is possible, the damage caused by invasive species. It is estimated that anywhere up to $27 billion of damage is caused by non-native plant species in the US alone, and $8 billion is spent on controlling weeds in agriculture (Barbier, et al., 2013). Tourism poses a great threat to the wildlife of the United States and many other countries. While it is known that invasive alien species pressure is driving declines in species diversity (McGeoch, et al., 2010), and that the human assisted rate of invasion is around 35,000 species/million years (in contrast with the natural rate of 0.33 species/million years (Ricciardi, 2007), the details of the effects at a smaller scale, as well as the extent of invasion is largely unknown due to a lack of funding to accrue data, and sampling of alien species across the globe.

While it was necessary to accept the null hypothesis that the number of annual tourists per national park is not directly correlated to the extent of alien species invasions, this is not the only conclusion. It is clear from this just how little we know about the drivers and impacts of alien species invasions – the correlates and causes are still unpredictable and more focus ought to be placed on developing an understanding of the dynamics of such species, their drivers and their effects. In an increasingly interconnected landscape, conservation science must not simply focus on small picture work, but look at the increasing effects we have worldwide, from decreasing heterogeneity to large scale trophic impacts, and the resulting shifts in ecosystem functioning. An insight into the dynamics and control of alien species invasions will undoubtedly be crucial for conservation efforts in the years to come.

Tables and Figures



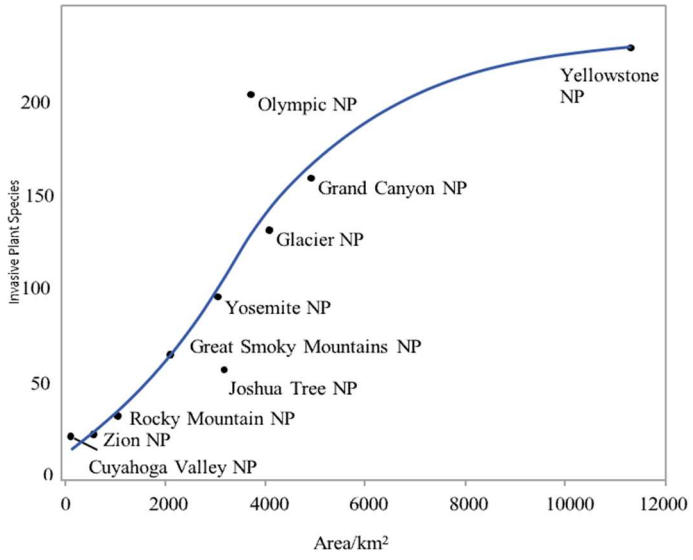


Fig 1, & 2 (left to right) – Fig. 1 shows the results of a comparison between average yearly visitors over the last 6 years and the values for invasive species in each park. The results suggest there is no correlation. Fig. 2 shows a comparison of park size and invasive alien species numbers. This shows a clear increasing trend as area increases – in keeping with the principle in ecology that the

number of species ought to increase as the sampling area increases. The number of invasive species seems to plateau but then again only 10 parks were assessed so this sample size may not be large enough to draw such a conclusion.

Table 1 – this contains all the data accrued for each of the parks, at the bottom is a total. This total is interesting as it shows the average number of species per km^2.

National Park	average visitors	Visitors /1000000	invasive species	park area/area	Park area/km^2	Number of Invasive Species/ km^2
Cuyahoga Valley NP	2,337,427	2.337	16	32572	131.9166	0.121288754
Joshua Tree NP	2,619,189	2.619	52	790636	3202.0758	0.016239466
Glacier NP	2,722,044	2.722	127	1012837	4101.98985	0.030960584
Olympic NP	3,150,903	3.151	200	922,650	3736.7325	0.053522697
Yosemite NP	4,036,098	4.036	91	759620	3076.461	0.029579442
Yellowstone NP	4,068,834	4.069	225	2798080	11332.224	0.019854885
Zion NP	4,141,390	4.141	17	146597	593.71785	0.028633129
Rocky Mountain NP	4,279,410	4.279	27	265600	1075.68	0.025100402
Grand Canyon NP	5,499,465	5.499	155	1218375	4934.41875	0.031412008
Great Smoky Mountains NP	11,571,503	11.572	60	522427	2115.82935	0.028357674
TOTAL	**44426261**	**44.426261**	**970**	**8469394**	**34401.0457**	**0.028196817**

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