UNIVERSITY OF GOTHENBURG

DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES

NON-NATIVE PLANTS IN MOUNTAIN ECOSYSTEMS:

An exploration of plant diversity and its response to road disturbance and alien invasion

Lina Anderberg

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Supervisor: Anne Bjorkman
Examiner: Johan Uddling Fredin

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Abstract

Understanding patterns of invasive plants becomes ever more important as anthropogenic presence continues to facilitate their spread. In mountainous landscapes, cases of establishment by non-native species have become frequent, despite the environmentally unfavorable conditions for plants less adapted to the harsh climate. This development can be attributed much to the construction of mountain roads at high elevations, as they provide both a means of seed transport and the disturbance in the vegetation cover needed for germination. Along with an increased presence of non-native species comes the inquiry of threat to biodiversity: Are these supposed invaders reducing the richness of native plants? This study examines the relationship between elevation, road proximity and presence of non-native plants as factors affecting species richness, a simple measure of biodiversity. The analysis uses data gathered following a standardized protocol provided by the MIREN research organization, sampled in Norwegian mountains. Results show that non-native species richness decreased with elevation and were highest in abundance near the low-lands. Richness was on average 14.1 species higher in roadside than natural vegetation. The relationship between non-native and native richness was positive (1.57 increase per unit), showing no sign of negative biotic interactions. An interaction between non-native species richness and road proximity was not found. The results support previous studies, giving strength to the conclusion that human activity is changing the distributional patterns and diversity of plants in mountain landscapes. It also implicates that close attention to new arrivals and preventative measures are important tools for managing potentially invasive species.

Innehållsförteckning

1. Introduction
1.1 Alpine ecosystems and the distribution of invasive species
Mountain and alpine landscapes are still considered to be ecosystems largely untouched and pristine (Pauchard et al., 2009; Pyšek et al., 2011). Although human presence in mountain landscapes are ancient (Guo et al., 2018), and traditional land use such as hunting and pasturing still persists in parts of the world its inaccessibility, and often harsh living conditions with low temperatures and soil unsuitable for agriculture, has left the mountains mainly uninhibited and unexploited (Körner, 1999). In recent years, however, increased anthropogenic activity has started to change the landscape. Tourism, skiing and exploitation like mining in the mountains becomes more common along with a growing world population (Guo et al., 2018). Additionally, global warming is reported to be higher in polar latitudes and high altitudes, making alpine ecosystems particularly sensitive (Körner, 1999; Rantanen et al., 2022). As anthropogenic presence and global warming are both expected to increase further, changes in community composition of alpine vegetation as a consequence of these factors have become a growing topic of research in recent years. Since mountains provide important ecosystem services and can be rich in cultural heritage (Körner, 1999), research can provide insights into better preservation and conservation measures for these fragile ecosystems.

Because disturbance and exploitation are still relatively infrequent in mountains, these ecosystems also remain largely uninvaded by invasive plant species (Becker et al., 2005; Guo et al., 2018; Pauchard et al., 2009). But what was once a biome believed to be inherently resistant to invasions (Pauchard et al., 2009) has recently seen movements of invasive plants into new habitats and higher elevations (Becker et al., 2005), posing a threat to native flora and overall diversity. Though, the extent of impact these migrations have in alpine regions remain largely unsolved (Seipel et al., 2012). An invasive species tend to be of exotic origin, but native species with expanding ranges can be equally problematic if displaying characters similar to invasive species, typically dramatic growth of population size and competition with other species (Simberloff, 2011). Most frequently, invasive species found in alpine regions originate from a lowland species pool (Alexander et al., 2011). The occurrence then typically decreases with altitude (Iseli et al., 2023), regardless of world region (Alexander et al., 2011). This distribution pattern can be explained by environmental filtering as newcomers to a region are often less well adapted to low temperatures, snow cover, drought, high exposure to wind and UV-radiation (Andersen et al., 2015; Moser et al., 2005).

The tendency of a plant to be invasive or display invasiveness in a particular area is generally determined by its ability to disperse quickly and the size of its native range (Alpert et al., 2000). If a species is foreign, but show less invasive tendencies, it might be labeled as just non-native. Invasive, or non-native, species in alpine ecosystems seem to be characterized by clonality and are more commonly perennial than annual (Andersen et al., 2015; McDougall et al., 2018). They are often generalists, with high adaptability and tolerance to many different environmental conditions; traits that are advantageous in alpine climates (Caplat et al., 2013). Further, species of European and Asian origin have been shown to be significantly more common as invasives globally (McDougall, Alexander, et al., 2011), highlighting the impact that historical trade and migration by these countries have had (Seipel et al., 2012). Any habitat to which a potentially invasive species arrives can be more or less susceptible to its establishment, generally referred to as its invasibility (Alpert et al., 2000). This measure depends partly on climatic restraints, but also on propagule pressure (Pauchard et al., 2009). Propagule pressure is dependent on the quantity and frequency of introductions to the habitat, which in turn increases with the number of visitations to the habitat (Pauchard et al., 2009). Increasing anthropogenic presence in alpine landscapes will therefore lead to more invasions.

1.2 Roads as vectors for invasions

As a consequence of increased human presence in mountain areas, infrastructure like roads become more frequent to facilitate transportation of goods and to support tourism. Roads are associated with a change in ecological conditions that can alter adjacent species composition by influencing hydrology and soil quality (Barros et al., 2022). The presence of a road also create disturbance in the form of habitat loss and fragmentation of surrounding vegetation (Kollarou et al., 2013). Several studies, carried out in various mountain regions in the world, have shown a greater species richness of non-native plants alongside roads (Arévalo et al., 2005; Barros et al., 2022; Ratier Backes et al., 2023; Seipel et al., 2012). This distribution can be explained by vehicles and footwear acting as vectors for dispersal, facilitating the spread of both native and non-native species. Potentially invasive plants can in this way expand into higher elevations (Ratier Backes et al., 2023; Taylor et al., 2012). Studies have further proposed that it is the direct, physical, disturbance caused by driving and trampling that acts to reduce biomass and thus competition, favoring early successional stages in the immediate surrounding terrain (Lembrechts et al., 2014; Ratier Backes et al., 2023). Non-native species, that are often ruderal and generalistic, will as a consequence have higher chances of establishing themselves in the new habitat (McDougall et al., 2018).

1.3 Effect on diversity of native plants

Invasions by plants are said to be a large driver of biodiversity loss (Alexander et al., 2011; Alpert et al., 2000; IPEBS, 2019). Numerous studies of the impact from invasive species on recipient ecosystems have shown an overall negative change in several physical conditions (Ehrenfeld, 2010), which in turn alter ecosystem functioning including interactions. Most commonly, invasive plants influence nutrient availability and fluxes, biomass production and mineralization as well as temperature and light accessibility (Ehrenfeld, 2010). In a review article, Pyšek et al. (2012) presents a global overview of the impacts that invasive plants have on both resident biota and the direction of change in resident communities following invasion. A decrease in several impact measures was found in a clear majority of studies: Survival, abundance, species richness, species diversity and productivity of resident biota were all affected negatively (Pyšek et al., 2012).

The definition of biodiversity has been a long-debated topic, giving rise to various explanations of the concept. The term can encompass whole ecosystems, species, genes as well as processes or other measures of complexity (Gaston, 1998). To be able to estimate and compare biodiversity between systems, mathematicians have developed several indices over the years; the many versions indicating the differences in inclusivity and interpretations that the term biodiversity holds (DeJong, 1975). One such index is Pielou's Evenness Index, a metric that considers both species richness and the evenness of a community (Jost, 2010). A value of 1 represents a community where all species are equal in numbers. In this study, the Pielou's index will be used, to better describe the plant composition in the target region by capturing their relative abundance.

1.3 Project aim

Since diverse communities have been shown to display higher ecosystem functioning and viability, the preservation of biodiversity is of great importance (Tilman et al., 1996). A basic measure of biodiversity is species richness; simply the number of species present in a particular area. As previously stated, several studies have shown an increase in species richness alongside roads as an effect of disturbance (Lembrechts et al., 2014). Others have shown how the establishment of non-native species is facilitated by roads (Barros et al., 2022). Still others show that invasive plants are causing biodiversity loss (Alexander et al., 2011). We could therefore expect an increase in non-native species, but perhaps a decrease in native species as an effect of competition from non-native plants. However, little is known about how these two factors relate to each other and how varying richness can be attributed to competition, in contrast to road disturbance.

To answer questions on this topic, this study will use a dataset acquired from the Mountain Invasion Research Network (MIREN), a global effort to broaden the understanding of plant diversity and alpine ecology (Haider et al., 2022). The survey monitors species distribution and redistribution by repeated recordings of both roadside and distant, undisturbed vegetation. In each of these communities, both occurrences of native and non-native plants have been recorded. By comparing these types two of vegetation, this project aims to investigate how alpha diversity changes in relation to road disturbance and the presence of non-native species. These two factors will be contrasted to each other, in an attempt to disentangle their respective impact on native flora. The overall research questions are: *Do species richness increase adjacent to mountain roads?* And if it does not: *Is this difference in richness caused by the disturbance inherent to roads or is it caused by competition from non-native plants? Is there a positive interaction between these two factors, indicating an amplification effect from non-native species on native species richness in a disturbed environment?*

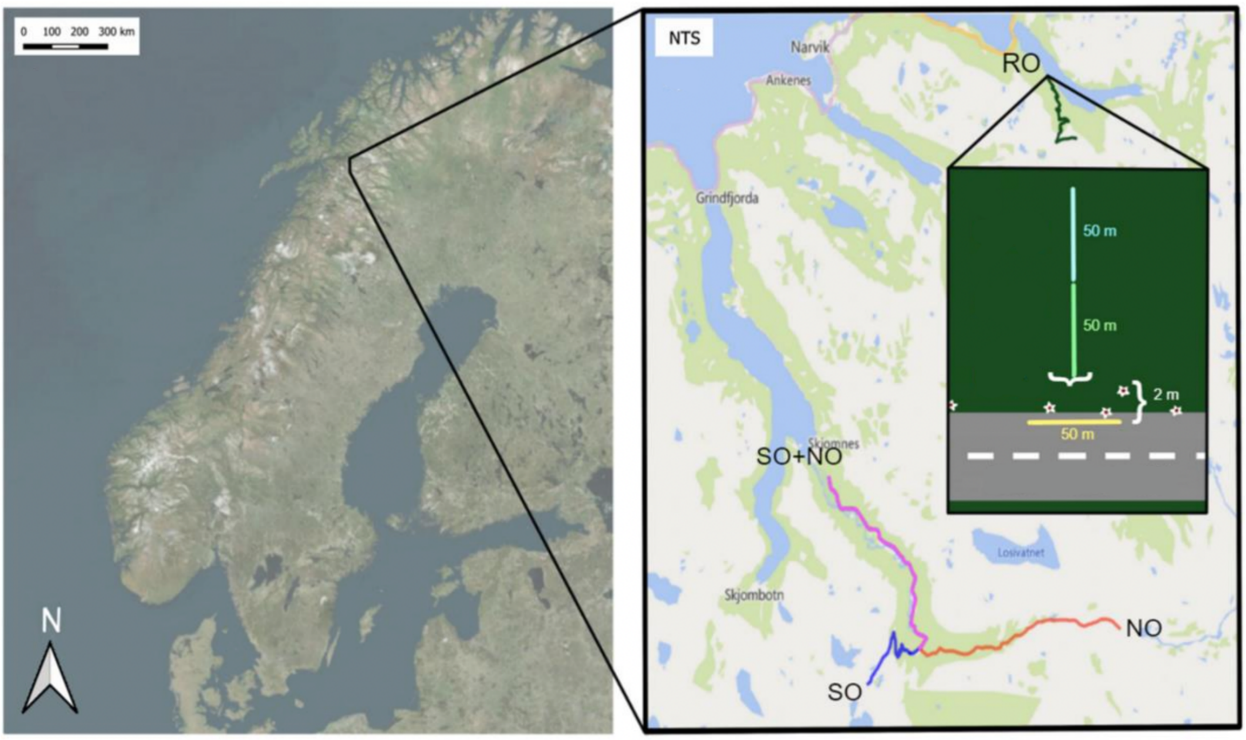
Understanding the patterns of non-native species movement and effect on diversity can help to understand the consequences of invasion in an environment which still displays low invasibility, as well as providing insight into appropriate conservation measures. Anthropogenic presence and climate change are both expected to increase, and alpine landscapes can be associated with important cultural heritage. Because of this, it is important to raise attention to negative changes in these environments (Körner, 1999).

2. Method

2.1 Survey design

Data for this project has been sampled during summer 2017 according to the standardized protocol provided by MIREN (https://www.mountaininvasions.org/). The sample area is located in the Northern Scandes near Narvik, Norway, where the survey is repeated at five-year intervals for long-term results. In this mountainous landscape, three roads have been selected (Figure 1), spanning the highest possible elevational range (13.2 - 703.7 m a.s.l) (Haider et al., 2022). Roads are further divided into 19 bands equal in elevation and survey sites are located at every split between two bands, resulting in 20 sites at every road (Figure 2a). What side of the road to be sampled is chosen at random. At every site three plots with 2 x 50 m area are laid out in a T-shaped transect: One parallel to the road (1), in this study called the 'roadside' plot, and two at a perpendicular angle with the centers at 25 (2) and 75m (3) away (Figure 2b). For this study, only plot 1 and 3 are used. Vegetation in plot 3 can be considered unaffected by road disturbance and contain natural plant communities, hereafter called the 'natural' plot.

In every plot, all observations of angiosperms, gymnosperms and ferns are determined to species level. If this precision is not achievable, plant observations can instead be recorded as a higher taxonomic level. Further, the cover of every species in a plot has been recorded along an ordinal scale with 8 classes representing the percentage of total area. (1 = < 0.1%, 2 = 0.1–1%, 3 = 2– 5%, 4 = 6–10%, 5 = 11–25%, 6 = 26–50%, 7 = 51–75%, 8 = 76– 100%). The status of each plant species has also been noted as 'native', 'alien' or 'unknown', determined by using regional floras (Haider et al., 2022). In this study, the terms 'alien' and 'non-native' will be used interchangeably. Although these plants are considered to be non-native, generally defined as being introduced after 1500 AD (Haider et al., 2022), no species are yet to be determined as invasive (Lembrechts et al., 2014).



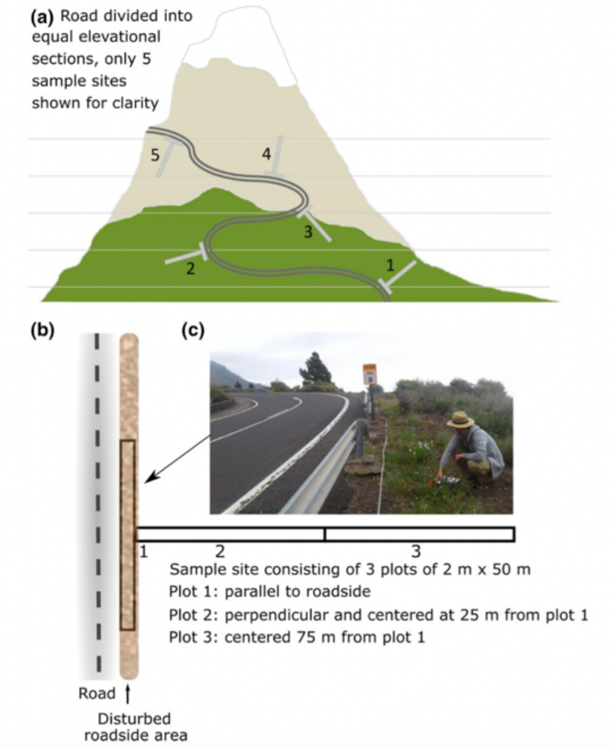


Figure 1 (*above*). *Location of sampling sites, near Narvik in Norway (68°26'18" N, 17°25'40" E). Right figure displays the three individual roads, labeled as RO, SO and NO. Image by Violetta Chernoray, from study "Mountain roads and the homogenization of plants".*

Figure 2 (*left*). *Survey design for the international MIREN-project, showing in* **(a)** *a simplified illustration of the layout of transect sites where samples are taken, each transect at equal elevational distance.* **(b)** *Plot design at each transect site. Plot 1 is parallel to the roadside, in this study referred to as "roadside plot". Plot 3 lies at 50-100 m from the roadside, at a 90° angle, in this study referred to as "natural plot". Image from Haider et. Al (2022)*

2.2 Data handling and statistics

All data handling and statistical analyses were performed in RStudio v. 4.1.2 (Team, 2021) using package *dplyr* for data handling, *ggplot2* for graphics as well as *emmeans* for summaries from performed ANOVAs. From the original dataset provided by MIREN, all observations belonging to plot 2 were removed considering they are not relevant to the present research question. Further, observations where status was labelled as "unknown" were removed in order to correctly assign all species to either "native" or "alien". This action was only relevant for one species (*Achillea millefolium*) and consequently should not affect results considerably.

Complementing species richness as a response variable, the Pielou's evenness index was calculated for each plot. Pielou's index uses the proportion of each species, but since the percentage of each observation had not been recorded during the sampling, the index was calculated by using the cover variable (its classes explained above). The classes, 1-8, were treated as numerical values and could thus be used to calculate their proportion in each plot. This method deviates from the proper way of calculating the index and the results should consequently be regarded as slightly unreliable and limited in applicability. However, it could be considered as an adequate analysis for this type of project.

2.3 Statistical tests

All numerical values have been checked for normality with Shapiro-Wilks tests. Response variable *over-all species richness* were found to follow an approximate Gaussian distribution, while *native species richness* and *non-native species* were significantly different from normal.

As a consequence of survey design and sampling method, data follows a nested structure. Individual plots are nested within roads, meaning plots belonging to one road are likely to be more similar than to plots belonging to others. Further, the elevation above sea level on which each plot is situated on have been shown to affect over-all species richness and could also impact the results in this project. To assess the degree of independence for these two variables, ANOVAs were performed for *species richness ~ road identity* and *species richness ~ elevation.* Results show both factors could be considered confounding and non-independent, but *road identity* to a lesser degree.

To determine the general effect from road proximity on species richness, several ANCOVA's were performed, with elevation and road identity as covariates. ANCOVA's were also performed for testing interaction and evenness. A Pearson's correlation tests were used for examining the relationship between elevation and species richness, and a linear model for testing the response on native richness from alien richness.

3. Results

3.1 Overall and elevational distributions

In total, 203 species were found over 120 sites along the three mountain roads in Northern Scandes, Norway. Of these, 13 species are classed as non-native (6.4% of all plant species). The three most common species were *Empetrum nigrum*, *Betula pubescens* and *Deschampsia flexuosa*, all of which were found at 100 or more sites each (Table 1). 35 species were only found once across all sites.

Examining overall richness in the area, an average of 28.4 ± 0.9 (n = 120) species were found in each plot. Species richness changed slightly along the elevational gradient from sea level to 703.7 m a.s.l., but the distribution can not entirely be considered as statistically significant from random (Pearson's, $r = 0.18$, $p = 0.086$). However, the distribution of alien species clearly decreased with elevation (Linear model, $t = -4.58$, $p < 0.001$) and showed a much higher richness in lower altitudes, as is apparent in Figure 3. Between the three roads surveyed, overall richness was similar (ANOVA, $F = 1.41$, $p = 0.249$).

Table 1. *The 10 most common native and non-native species with the total number of observations over all 120 plots located in the study area.*

Native species	Observations	Non-native species	Observations
Empetrum nigrum	106	*Trifolium repens*	28
Betula pubescens	105	*Trifolium pratense*	14
Deschampsia flexuosa	100	*Phleum pratense*	10
Solidago virgaurea	97	*Poa annua*	6
Vaccinium myrtillus	92	*Plantago major*	4
Salix spp.	89	*Tanacetum vulgare*	3
Vaccinium vitis-idaea	89	*Festuca pratensis*	2
Vaccinium uliginosum	87	*Matricaria suaveolens*	2
Sorbus aucuparia	80	*Stellaria graminea*	2
Lysimachia europaea	79	*Vicia cracca*	2

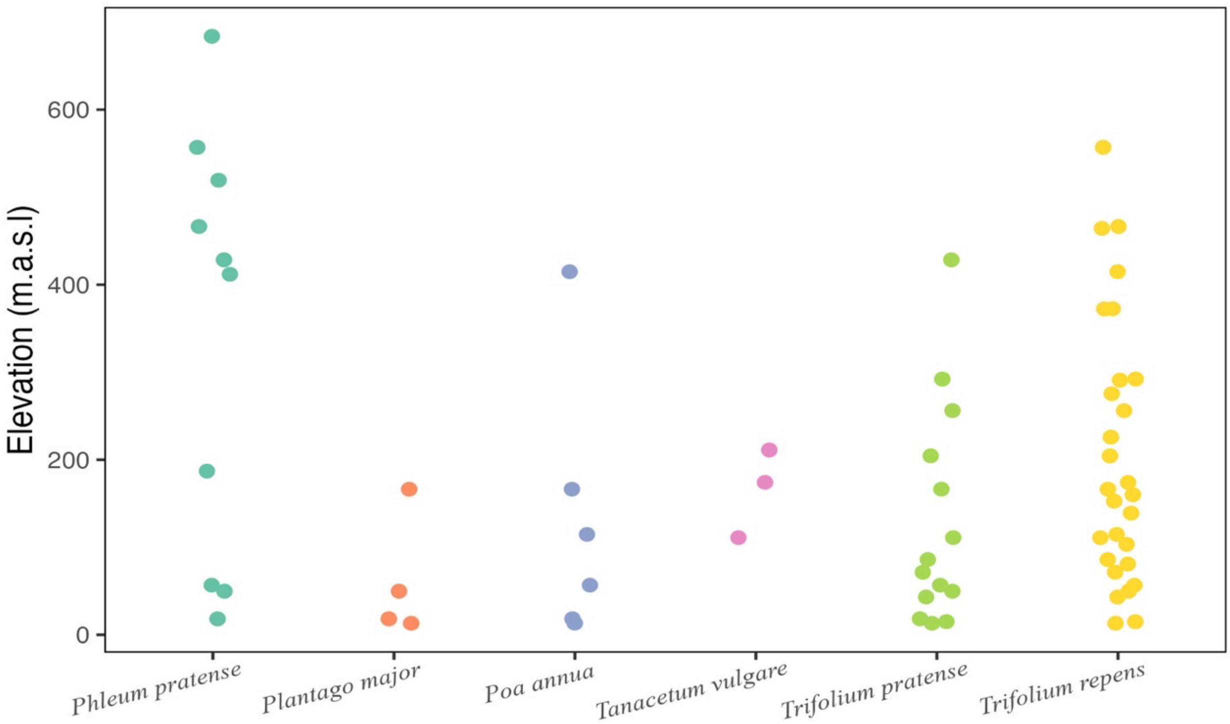


Figure 3. *Elevational distribution for six of the most commonly non-native species in the study area. Each point represents one observation. Total number of observations for selected species are 65, and maximum elevation is 703 m a.s.l.. Non-native species show a clear decrease in richness with higher elevation.*

3.2 Road proximity and native – alien relationship

Species richness was generally higher adjacent to roads than in natural vegetation. For roadside plots, mean values were 35.5 ± 0.98 (n = 60) and the distribution was fairly homogeneous along the elevational gradient (Pearson's, $r = 0.05$, $p = 0.660$). In the natural plots species richness was 21.4 ± 0.9 (n = 60) and an increase could be seen with higher elevations (Pearson's, $r = 0.41$, $p < 0.001$) (Figure 4).

Overall species richness was highly affected by proximity to the road, an average of 14.1 more species in the roadside plots (ANOVA, $F = 109.1$, $p < 0.001$) (Figure 5a). The same relationship is found when examining native species richness (ANOVA, $F = 96.5$, $p < 0.001$) and alien species richness (ANOVA, $F = 53.3$, $p < 0.001$) separately as responses to road proximity. Both groups show higher richness by the road. However, only two observations of alien species were made in the natural plots, compared to 74 observations total in roadside plots.

Further, the relationship between alien and native species richness was positive, meaning an increase in alien observations in a plot is associated with a 1.57 increase in native observations (Linear model, $t = 2.11$, $p = 0.037$). To control for plot-to-plot variability and the disturbance effect found in road margins, *road proximity* was used as a covariate along with *elevation.*

Although species richness in roadside plots were generally higher, the evenness (Pielou's index) of the species composition was higher in natural vegetation (ANOVA, $F = 100.4$, $p < 0.001$), indicating that some species might be more dominant along the roads (Figure 5b).

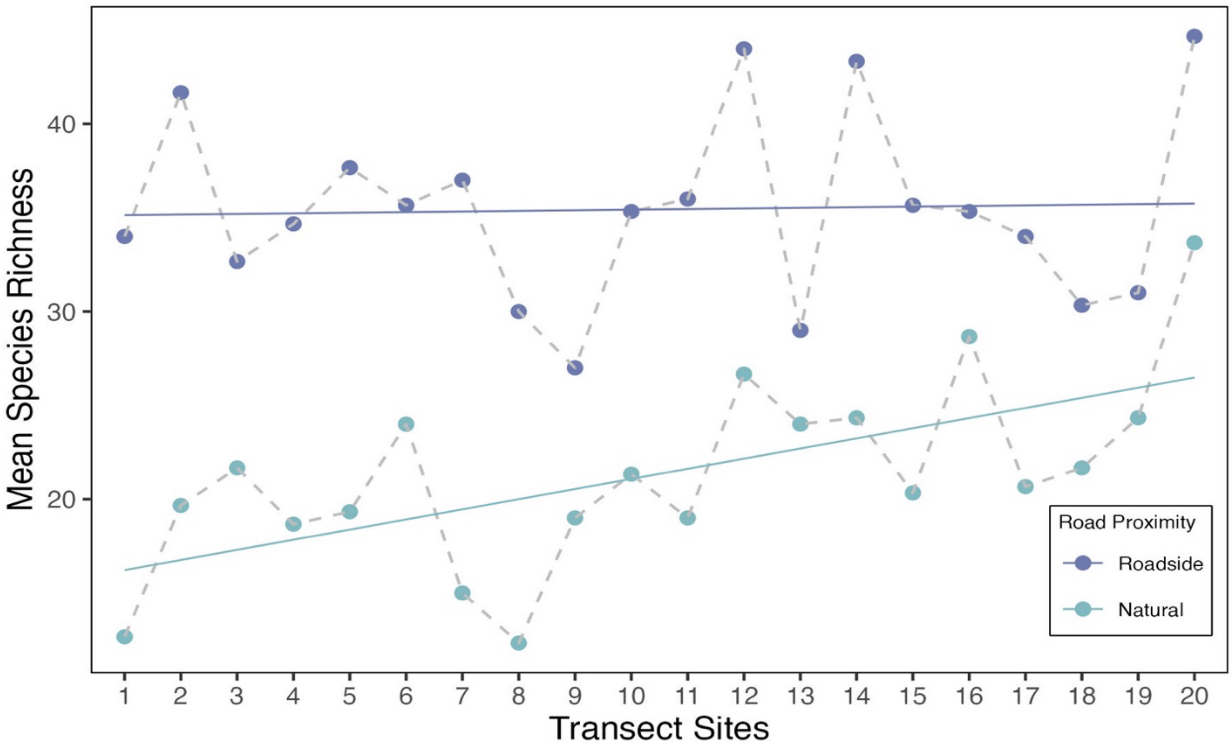


Figure 4. *Mean species richness for all 20 transect sites. Values are averages of the three sampled roads. The transect sites represent lines between elevational bands, equal in altitudinal difference from the base to the highest point reachable by vehicle. The variable can therefore present species richness as a response to elevation. No relationship was found for roadside plots (indigo), but an increase is found for natural plots (turquoise),*

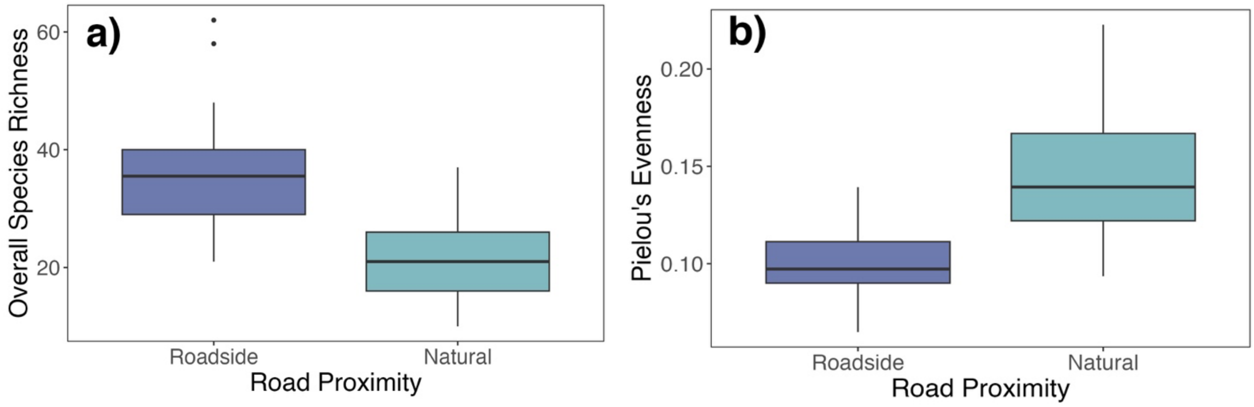


Figure 5a. *Difference between overall species richness in roadside and natural plots. A clear difference is found.* **b.** *Pielou's evenness index displayed for roadside and natural plots. Mean value for roadside plots are 0.1* (± *0.002*) *and for natural 0.15* (± *0.004*)*. Natural plots show more evenness between species.*

3.3 Interaction

No interaction between road proximity and alien species richness on the overall species richness was found (ANOVA, $F = 0.70$, $p = 0.40$). The results indicate that an amplification effect is not found, competition from non-native plants is not stronger in disturbed areas than undisturbed. Rather, the disturbance that is associated with road margins seems to support a higher species richness of both native and non-native species, and is the primary factor determining differences in alpha diversity between roadside and natural areas (Figure 6).

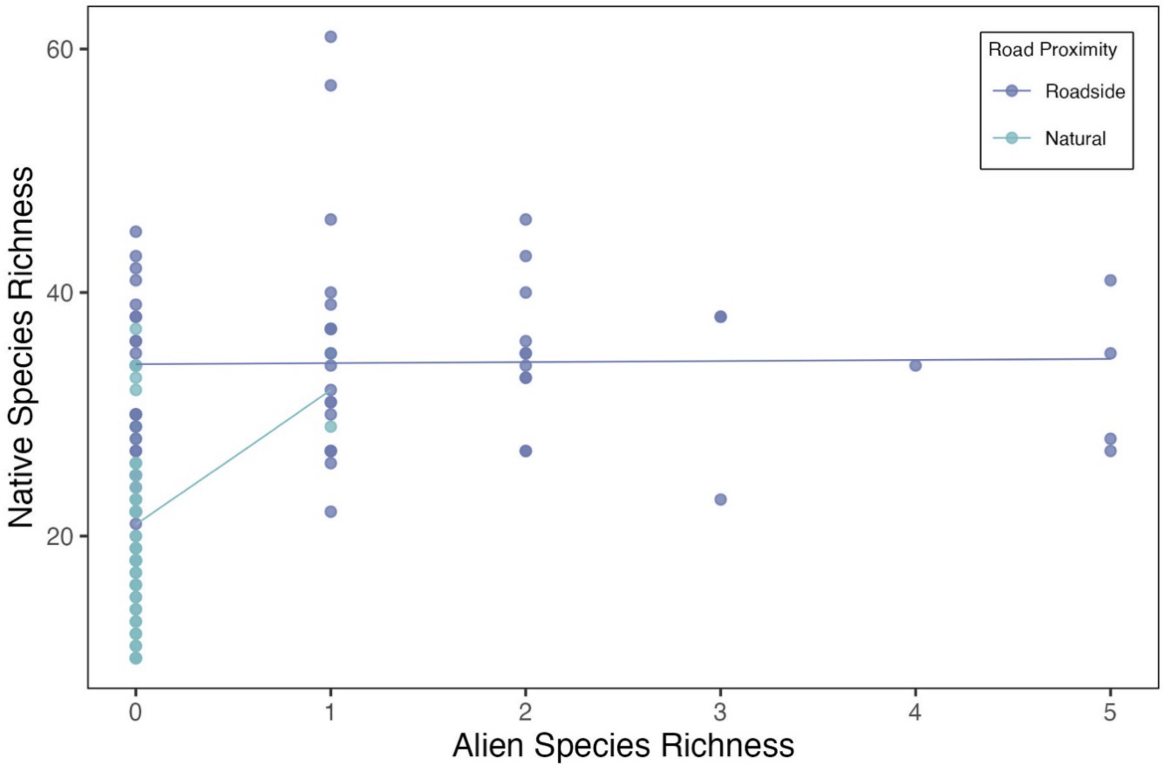


Figure 6. *Relationship between native and alien species richness, separated for roadside (n = 60) and natural plots (n = 60). Roadside plots are shown in indigo and natural plots in turquoise, lines show correlation between the two variables. No correlation can be found for roadside plots (r = 0.015, p = 0.906), but the relationship is significant for natural plots (r = 0.273, p = 0.035). However, only two observations of alien species were made in the natural plots and the test is therefore very weak.*

4. Discussion

The results show that alpha diversity is indeed higher adjacent to mountain roads. Further, there are more non-native plants closer to the road than in the natural vegetation, indicating that roads are also facilitating their spread. However, the separate effects from road disturbance and non-native species on native species richness proved to be difficult to disentangle. The interaction between these two factors was not particularly strong. Regarding the quantity of non-natives, there are still relatively few species observed in the region. Norwegian mountains are, as previously mentioned, still fairly uninvaded (McDougall et al., 2018). In a previous MIREN-study conducted along the same three roads in Northern Scandes, only 11 alien species (5%) were identified (Lembrechts et al., 2014), two less than in the 2017 dataset used for this study. These numbers can be compared to a study performed in Canary Islands, where a total of 39% of all plant species were classed as invasive (Arévalo et al., 2005).

In the same Lembrechts' study from 2014, overall results are similar and support some of the results presented in this study. Particularly, they found that roadside plots had higher native species richness than plots far away (Lembrechts et al., 2014). Further, the elevational distribution, divided by road proximity, closely resembled those presented here (Figure 4). They, too, concluded an increase in species richness in natural plots, but roadside plots showed no direction of change as altitude increases. Comparing these two studies can give some support to the hypothesis presented here. However, finding similarities between the results can, in this case, not strengthen conclusions about alpine diversity in general, since the data could be considered a form of pseudoreplication.

Both the elevational patterns of non-native species and the compositional differences between roadside and natural vegetation can be explained by the disturbance caused by roads. Globally, native species are commonly unimodal in distribution with a slight peak at lower-mid ranges. In contrast, alien species usually decrease with higher elevations (Alexander et al., 2011; Grytnes et al., 2008; Guo et al., 2018; Haider et al., 2018; Iseli et al., 2023). This distribution is clearly a consequence of heightened propagule pressure from roads, and the ability of a non-native plant to establish at high altitudes is assisted by reduced competition and higher nitrogen availability (Lembrechts et al., 2017). From the roadside, non-native plants move and expand their ranges into adjacent natural vegetation, rather than directly from the neighboring lowland (McDougall et al., 2018). This mode of spreading has been well defined in previous literature, and could explain why only two observations were made in the natural plots in this dataset.

When examining the evenness of the communities, results show that natural vegetation is more even. This indicates that roadsides might be favoring the dominance from a few, competitive plant species. As has been hypothesized in previous research, disturbance is the key factor for takeover by ruderal, fast growing and expansive species (McDougall et al., 2018). Despite the clear difference found, caution needs to be taken when interpreting this association. The calculation of Pielou's evenness index was performed using classed species cover, contrary to proportion as the formula calls for. Index values are consequently slightly unreliable.

4.1 Invasiveness and invasibility

The degree of invasion from roadside plots into adjacent natural vegetation is dependent on both species traits and the characters of the resident vegetation (McDougall et al., 2018). These traits, such as height and reproduction strategy (Pyšek et al., 2012), are important research topics to allow predictions of invasiveness for particular species. It might even help to understand how invasive plants influence homogenization of communities (Haider et al., 2018). It is, nonetheless, beyond the scope of this study. As previously mentioned, the biotic interaction from invasive plants is typically negative for native species richness and diversity (Choler et al., 2001; Pyšek et al., 2012). In contrast, the results show that as alien species richness increases, native richness does too, even though the effect from road proximity has been removed. Several reasons could explain this. Firstly, the response from the road disturbance is so strong on species richness that removing its influence during the analysis is not sufficient. To account for this, the survey design could be done differently. Secondly, no species have been classed as invasive (Artsdatabanken, 2018). The species are established after the year 1800, but are yet to show signs typical for invasives, such as rapid expansion and harm to native communities (Davis & Thompson, 2000). That makes impact evaluation somewhat difficult to determine, and increasing the certainty calls for using plants that have been established as invasive.

Biotic interactions can further help facilitate the establishment of plants in areas where they have previously not been found (Choler et al., 2001). How this relates to mountainous flora and elevational distribution is yet to be explored (Roux et al., 2012). Overall, studying invasiveness, invasibility and similar measures seems to be faced with difficulties. Although the urgency to limit the spread of invasive plants increase rapidly, the theory around impact and positive or negative consequences might sometimes become excessive.

4.2 Limitations, future studies and implications for management

The sampling protocol provided by MIREN ensures replication and consistency when comparing different areas around the world. However, using only the dataset from 2017 sampled in Northern Scandes does not allow for analyzing temporal variation or extrapolation to other geographical regions and ecosystems. Further, many environmental factors not included in this analysis might influence the patterns of diversity, such as soil quality and nutrient content. The degree of bare ground in each plot has also been ignored for simplification purposes, despite it being a measure that would give some information about the available space for vegetation to grow and could therefore affect the evenness metric.

For examining only the proposed negative effect that non-native or invasive species have on native species richness (Alexander et al., 2011; Alpert et al., 2000; IPEBS, 2019), the study could have been performed in a better way for stronger and more reliable results. Rather than using plots associated to mountain roads, only using plots with known sites for invasives and comparing species richness in natural vegetation would directly answer if a negative impact exists. In this case, only having 60 natural plots resulted in few datapoints of non-native observations and weaker statistical certainty. Likewise, total sample size should be increased if the study were to be repeated. It is also important to note that although this study finds correlations between factors, for example road proximity and species richness, it does not necessarily prove causality. To be able to determine the influence of other factors, and understand the mechanisms behind these correlations, additional research could be conducted to test and control for the different factors separately.

The results in this study support as well as highlights the importance of early assessment and attention when it comes to invasive species. Already, scientists in the field are calling for better proactive management in regions with little non-native flora, or sensitive ecosystems such as islands (Anderson et al., 2015). Anthropogenic activity will, most likely, continue to expand and alongside that continue to facilitate the spread and establishment of non-native species (Iseli et al., 2023; Seipel et al., 2012). As the climate becomes warmer - mountains and arctic landscapes being especially vulnerable (Rantanen et al., 2022) - distributional changes are expected. Increased productivity and more hospitable growing space on mountain slopes (Körner, 1999) will likely result in more invasive plants in alpine regions, calling for even greater urgency in preventional management (Caplat et al., 2013). Practical examples of management include minimizing damaging tourism, providing information for visitors, limiting transportation and the spread of organic matter into high altitudes by for example cleaning vehicles (Anderson et al., 2015; McDougall, Khuroo, et al., 2011). Where needed, expanding populations might need to be controlled by eradication, although this is often less cost-effective (Rejmánek, 2000). In this light, continuing to expand knowledge on alpine flora, both native and alien, will become increasingly important to understand their traits, interactions and distributional patterns.

Conclusion

This study shows that the construction of roads has a large role in facilitating the spread of non-native plants into mountain landscapes. The findings include higher richness of both non-native and native plants alongside roadsides, as well as lower evenness in species composition when comparing disturbed vegetation with natural. What needs further investigation is the possible impact, in terms of biodiversity change, that these newcomers could have on the resident flora. Studying the patterns of species distribution is important for understanding how diversity changes as a response to human activity. Since the northern Scandes is a region quite uninvaded by non-native or invasive plants, early assessments and proactive management is still possible.

Acknowledgments

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