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Roads act as corridors for the spread of alien plant species in the mountainous regions: A case study of Kashmir Valley, India

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Abstract: The distribution and abundance of alien plant species can be strongly influenced by corridors that facilitate their dispersal. Although roads have been implicated as an important contributory factor in biological invasions, their precise role as conduits in the spatial spread of alien species remains poorly understood. In order to investigate the role of roads in alien plant invasions, we explored diversity and abundance of native and non-native plant species along two road transects (50 and 56 km in length, respectively) and surveyed 5 sites (100 x 100 m) at each of these transects. The sites namely Zakoora, Gulabbagh, Daren Nagbal, Ganderbal, Kangan (along transect I) and Galendar, Lethpoora, Awantipoora, Sangam, Qazigund (along transect II) are located in four districts (Srinagar, Ganderbal, Pulwama and Anantnag) of Kashmir valley in India. Floristic surveys during the growing season in the study sites revealed occurrence of 197 vascular plant species. Out of these 136 species were non-native and only 61 were native. 57 non-native species were invasive, 71 naturalized and 08 were casual. Compared to alien plant species, richness and abundance of native species increased with increase in distance perpendicular to the road. The high percentage (69 %) of alien plant species in the roadside flora and also the greater number of alien plant species close to the roads clearly indicate that roadsides act as anthropogenic corridors for the spread of alien plant species.

Resumen: La distribución y la abundancia de las especies vegetales exóticas pueden estarinfluenciadas fuertemente por corredores que faciliten su dispersión. Aunque los caminos han estado implicados como un factor importante que contribuye a las invasiones biológicas, su papel preciso como conductos en la distribución espacial de las especies exóticas sigue estandomalentendido. Para investigar el papel de los caminos en las invasiones de plantas exóticas, exploramos la diversidad y la abundancia de especies de plantas nativas y no nativas a lo largo de dos transectos en caminos (50 y 56 km de longitud, respectivamente) ehicimos levantamientos encinco sitios (100 × 100 m) en cada uno de estos transectos. Los sitios Zakoora, Gulabbagh, Daren Nagbal, Ganderbal, Kang (a lo largo del transecto I) y Galendar, Lethpoora, Awantipoora, Sangam, Qazigund (a lo largo del transecto II) están ubicados en cuatro distritos (Srinagar, Ganderbal, Pulwama y Anantnag) del valle de Cachemira en la India. Los levantamientos florísticos durante la época de crecimiento en los sitios de estudio revelaron la presencia de 197 especies de plantas vasculares. De éstas, 136 fueron no nativas y sólo 61 fueron nativas. Cincuenta y siete especies exóticas fueron invasoras, 71 naturalizadas y ocho fueron casuales. En comparación con las especies exóticas, la riqueza y la abundancia de las especies nativas aumentaron con el aumento de la distancia perpendicular al camino. El porcentaje alto (69 %) de especies de plantas exóticas en la flora de la orilla del camino carretera, así comoel número mayor de especies de plantas exóticas cerca de los caminos, indican claramente que las orillas de los caminos sirvende corredores antropogénicos para la propagación de especies de plantas exóticas.

Resumo: A distribuição e abundância de espécies de plantas exóticas podem ser fortemente

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influenciadas por corredores que facilitam sua dispersão. Embora as estradas tenham sido implicadas como um fator importante que contribui para as invasões biológicas, seu papel preciso como condutores na propagação espacial de espécies exóticas continua a ser mal compreendido. A fim de investigar o papel das estradas nas invasões de plantas exóticas, explorámos a diversidade e abundância de espécies vegetais nativas e não-nativas ao longo de dois transeptos de estrada (50 e 56 km de comprimento, respectivamente) e inspecionaram-se cinco sítios (100 x 100 m) em cada um desses transeptos. Os locais, nomeadamente Zakoora, Gulabbagh, Daren Nagbal, Ganderbal, Kangan (ao longo do transepto I) e Galendar, Lethpoora, Awantipoora, Sangam, Qazigund (al longo transepto II) estão localizados em quatro distritos (Srinagar, Ganderbal, Pulwama e Anantnag) do vale da Caxemira na Índia. Os levantamentos florísticos, durante o período de crescimento nas áreas de estudo, revelarama ocorrência de 197 espécies de vegetais vasculares. Dessas, 136 espécies eram não-nativas e apenas 61 eram nativas. Das espécies não-nativas 57 eram invasivas, 71 eram naturalizadas e 8 eram casuais. Em comparação com espécies de plantas exóticas, a riqueza específica e a abundância de espécies nativas aumentaram com o aumento da distância perpendicular à estrada. A alta percentagem (69 %) de espécies de plantas exóticas na flora de beira de estrada e também maior número de espécies de plantas exóticas perto das estradas indicam claramente que aquelas atuam como corredores antropogénicas para a propagação de espécies vegetais exóticas.

Key words: Abundance, alien species, Himalaya, invasion, native.

Introduction

Invasion by alien species is considered to be second major threat to biodiversity worldwide which is in turn promoted by disturbance, fragmentation (Kumar & Mathur 2014; Raghubanshi & Tripathi 2009; Sharma & Raghubanshi 2010) etc. In non-native habitats, the spread of a species is limited by propagule pressure, abiotic factors and biotic interactions with competitors, consumers and mutualists, and all these factors may vary along environmental gradients, such as latitude, continentality and altitude (Dietz & Edwards 2006; Hallet 2006). A number of studies in recent decades have examined factors contributing to spread and successful colonization of exotic species in non-native habitats. Roads are often cited as contributing to the spatial spread of alien species, since they represent the primary pathways for the introduction of alien plant species, especially for generalist species with short life spans and high reproductive rates (Parendesand Jones 2000; Spellerberg 1998). Fortunately, most alien species growing along roadsides are incapable of colonizing less disturbed natural environments. Roadsides, however, may still serve as starting points for some species to spread from the edges to the interiors of pristine or naturally disturbed environments (Cadenasso & Pickett 2001; Murcia 1995). Roadsides are also reported to act as reservoirs of alien plant propagules that can be liberated during anthropogenic disturbance events (Parendes & Jones 2000) in natural habitats. Thus, roadsides provide both habitat and potential dispersal corridors for exotic plant species (Amor & Stevens 1975; Gelbard & Belnap 2003; Pauchard & Alaback 2006; Tyser & Worley 1992).

Because of their role in alien plant invasions, roads are important places to examine patterns of distribution of alien species and their potential for invasion into interior habitats (Trombulak & Frissell 2000). Additionally, roadsides are useful for studying influence of climatic factors and dispersal characteristics on alien species because the roads themselves provide a consistent disturbed environment across a wide elevational gradient (D'Antonio *et al.* 2001; Milton & Dean 1998; Spellerberg 1998; Tyser & Worley 1992; Wilson *et al.* 1992). At the local scale, habitat filtering may have an important effect on species richness and composition of roadside plant communities (Gelbard & Belnap 2003; Parendes & Jones 2000).

Although mountain ecosystems are considered to be at low risk of plant invasion due to their harsh climate and limited human activities but the promotion of mountain areas, particularly the Kashmir Valley, as global tourist destination has put these ecosystems at higher risk of invasion. It

is in this context that the present study was carried out to study (i) how do alien plant species distribute along roadsides? (ii) To what extent the richness and abundance of native and alien plant species are dependent on the perpendicular distance from the road?

Materials and methods

Study area

The present study was carried out in Kashmir Valley - a phytogeographically distinct south Asian region nestled in the northwestern folds of Himalayan biodiversity hotspot. The region has an area of about 15,948 km², with nearly 64 % of the total area being mountainous. The region lies between coordinates of 32º 20´ to 34º 50´ North latitude and 73º 55´ to 75º 35´ East longitude (Hussain 2002).

Study sites

The study sites were identified and selected using satellite imagery data, and available maps. A total of ten roadside sites (five along each transect) of 100 × 100 m size were selected along two road transects, 50 (transect I) and 56 (transect II) kms in length. These roadside sites were so selected that they were at least 500 m apart, so as to capture the uniqueness and variability across the sites. It is important to note that the sites namely Zakoora, Gulabbagh, Daren Nagbal, Ganderbal, Kangan (along transect I) and Galendar, Lethpoora, Awantipoora, Sangam, Qazigund (along transect II) are located in four districts (Srinagar, Ganderbal, Pulwama and Anantnag) of Kahmir valley.

Vegetation sampling

Present study was conducted employing stratified sampling (strata being herbs, shrubs and trees) technique using 1 m² quadrats as sampling units to survey vegetation along roads. In case of runners, each node was taken equivalent to an individual and in respect of other rhizomatous species each upright shoot was considered as an individual. Each study site was sampled thrice (representing three different seasons) during the year 2009 to compile a conspectus of the plant species growing in these habitats. This was done so as to collect flowering specimens of all the species as different species flower during different seasons. The plant specimens collected from various study sites were then identified using identified specimens of Kashmir University Herbarium. Quadrat data were used for computation of abundance by using following formula:

$$\text{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Number of quadrats in the which species occurred}}$$

At four sites (two along each transect), we located one 100 × 2 m² plot, selected randomly on one side of the road, with the larger side of the rectangle parallel to the road. We located another plot 100 × 2 m², perpendicular to the road an interior plot (Fig. 1), and then divided the perpendicular plot into 10 equal parts and recorded the richness and abundance of vascular plant species using a quadrat of 1 m² size.

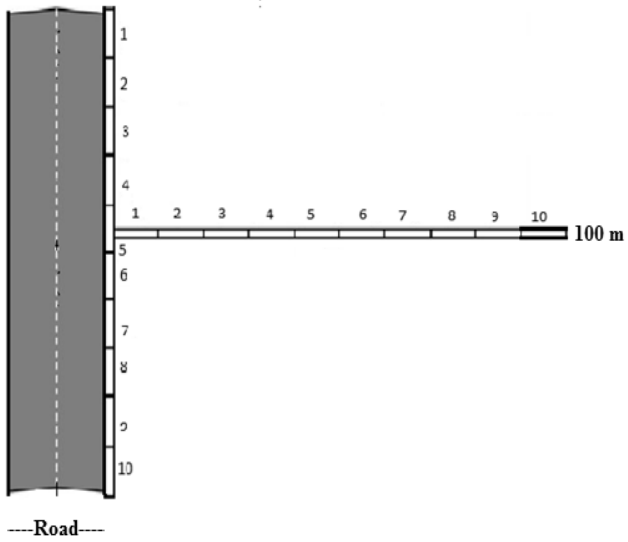

Fig. 1. Parallel and perpendicular plots.

Native geographical range of the plant species was obtained from various sources [mostly Khuroo *et al*. (2007) and specialised internet web pages (www.efloaras.org and GRIN)].

Data analysis

For evaluating the role of roads in the spread of alien species, Spearman's Correlation coefficient was calculated between perpendicular distance and richness (separately for native and alien species) and between perpendicular distance and abundance of species (separately for native and alien species) using SPSS software. Then the significance of the relationship was evaluated using t-test ($P < 0.001$).

Table 1. Distribution of native and alien plant species in various families.

Group/Family	Total no. of species	Total no. of native species	Total no. of alien species	No. of casual species	No. of naturalized species	No. of invasive species
Pteridophytes						
Equisetaceae	1	-	1	-	1	-
Monocots						
Cyperaceae	4	1	3	-	1	2
Iridaceae	1	-	1	-	-	1
Juncaceae	1	-	1	-	-	1
Liliaceae	1	1	-	-	-	-
Poaceae	27	9	18	1	11	6
Dicots						
Amaranthaceae	1	-	1	-	-	1
Apiaceae	9	3	6	-	4	2
Apocyanaceae	1	-	1	-	1	-
Araliaceae	1	1	-	-	-	-
Asteraceae	33	6	27	2	9	16
Balsaminaceae	1	1	-	-	-	-
Boraginaceae	6	2	4	-	3	1
Brassicaceae	14	4	10	2	6	2
Cannabiaceae	1	-	1	-	-	1
Caprifoliaceae	1	-	1	1	-	-
Caryophyllaceae	6	2	4	-	2	2
Chenopodiaceae	3	-	3	-	2	1
Convolvulaceae	2	-	2	-	1	1
Elaeagnaceae	1	1	-	-	-	-
Euphorbiaceae	3	-	3	-	2	1
Fabaceae	16	6	10	1	6	3
Geraniaceae	5	4	1	-	1	-
Lamiaceae	10	3	7	-	5	2
Malvaceae	3	1	2	1	1	-
Oleaceae	1	1	-	-	-	-
Onagraceae	2	-	2	-	-	2
Oxalidaceae	1	-	1	-	1	-
Papavaraceae	1	1	-	-	-	-
Plantaginaceae	2	-	2	-	-	2
Polygonaceae	7	3	4	-	2	2
Primulaceae	1	-	1	-	-	1
Ranunculaceae	7	2	5	-	2	3
Rosaceae	4	1	3	-	3	-
Rubiaceae	4	2	2	-	2	-
Scrophulariaceae	8	2	6	-	4	2
Solanaceae	2	-	2	-	1	1
Urticaceae	1	-	1	-	-	1
Verbenaceae	1	1	-	-	-	-
Violaceae	3	3	-	-	-	-

Table 2. Categorization of native and alien plant species collected from all study sites in different groups on the basis of growth form and life span.

				Alien		
	Category	Total	Native	Casual	Naturalized	Invasive
Growth form	Herbaceous	189	56	7	69	57
	Shrubs/Sub-shrubs/lianas	7	5	-	2	-
	Trees	1	1	-	-	-
Life span	Annuals	95	26	7	34	28
	Biennials	11	2	-	3	6
	Perennials	91	33	1	34	23

Results

The present study revealed the occurrence of 197 plant species. Out of these 136 species were alien and only 61 were native. Of the 136 alien species, 57 were invasive, 71 were naturalized and 08 were casuals. These species belonged to 40 families (1 pteridophyte, 33 dicot and 5 monocot families). The most representative families were Asteraceae (33 spp.), Poaceae (27 spp.), Fabaceae (16 spp.), Brassicaceae (14 spp.) and Lamiaceae (10 spp.) [Table 1].

Out of 197 species, 189 species (56 natives, 07 casuals, 69 naturalized and 57 invasive) were herbs, 07 (04 natives and 03 naturalized) were shrubs and only 01 (native) was a tree. Besides, 95 (26 natives, 07 casuals, 34 naturalized and 28 invasive) were annual, 11 (02 natives, 03 naturalized and 06 invasive) were biennial and 91 were perennial species (33 natives, 01 casual, 34 naturalized and 23 invasive) [Table 2].

The richness of alien species correlated negatively with the perpendicular distance of the roadside from road (r = -0.91, R^2 = 0.8405, P < 0.001, Fig. 2). The richness of alien plant species was maximum (i.e., 46 species m^{-2}) near the road and it gradually decreased reaching a minimum of 32 species m^{-2} at a perpendicular distance of 81 - 100 m from the road. On the other hand, the richness of native species correlated positively with the perpendicular distance of the roadside from the paved road (r = 0.63, R^2 = 0.4091, P < 0.001, Fig. 3). the native species richness was found to be minimum (i.e., 8 species m^{-2}) at a distance of 21 - 30 m; thereafter it increased and reached to a maximum of 20 species m^{-2} at a perpendicular distance of 91 - 100 m from the road.

The abundance of native species correlated positively with the distance from the roadside (r = 0.46, R^2 = 0.5991, P < 0.001, Fig. 4). The average abundance of native species was found to be maximum (i.e., 16 individuals m^{-2}) at a distance of 91 - 100 m with minimum at a perpendicular distance of 11 - 20 m from the road. Beyond the distance of 20 m from the road we observed a gradual increase in the average abundance of native species reaching up to a maximum of 16 individuals m^{-2} at the perpendicular distance of 100 m from the road. On the other hand the average abundance of alien species varied insignificantly with the perpendicular distance from the road (r =.77, R^2 = 0.2159, P < 0.001, Fig. 5).

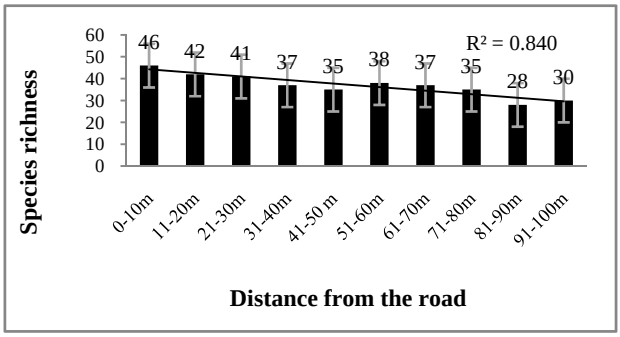

Fig. 2. Variation in alien species richness (species m^{-2}) along a gradient of 100 m from the road (r = -0.91, P < 0.001).

Discussion

The present study clearly reveals that roadsides harbour higher percentage of alien plant species (~69 %) as compared to native species (~31%). Other workers such as Gelbard & Belnap (2003); Parendes & Jones (2000); Tikka*et al*. (2001) have also obtained similar results. Several factors, such as greater dispersion due to traffic, higher amount of water and light, lower competition with

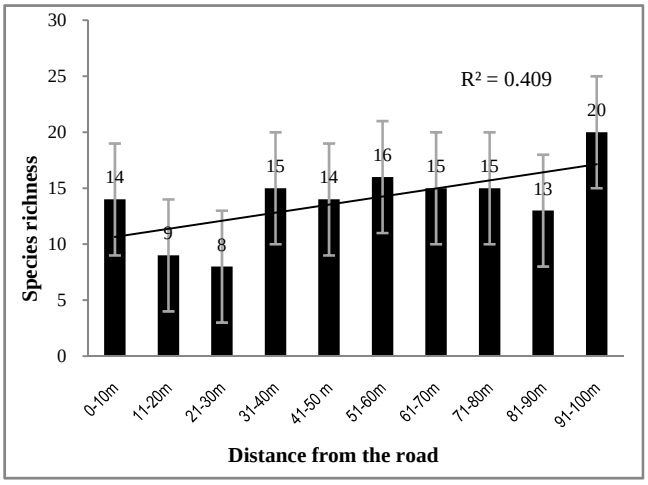

Fig. 3. Variation in native species richness (species m^{-2}) along a gradient of 100 m from the road (r = 0.63, $P < 0.001$).

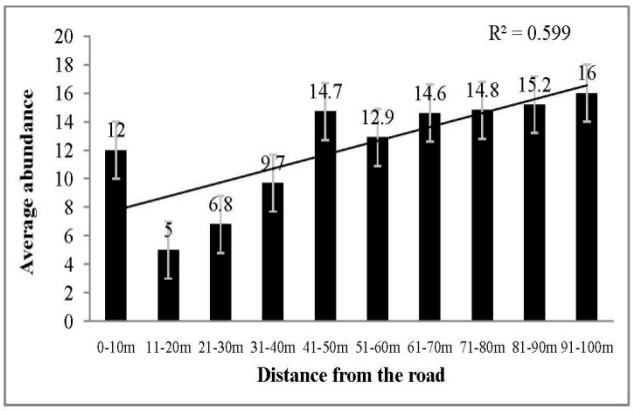

Fig. 4. Variation in average abundance (no. of individuals m^{-2}) of native species along a gradient of 100 m from the road (r = 0.46, $P < 0.001$).

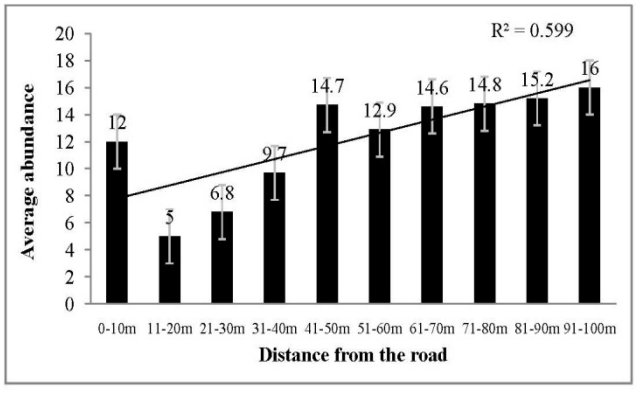

Fig. 5. Variation in average abundance (no. of individuals m^{-2}) of alien species along a gradient of 100 m from the road(r = 0.77, $P < 0.001$).

the dense native vegetation and physical and chemical changes in soil (Holzaphel & Schmidt 1990; Parendes & Jones 2000; Western & Jurvik 1983;), have been suggested to be responsible for a high percentage of non-native species at the edges of the roads. Road construction brings about considerable anthropogenic disturbances of natural communities, baring soil, clearing natural vegetation, admitting light to the ground layer, and altering drainage (Christen & Matlack 2006) and as such creates habitats that are suitable for colonization by invasive species, which are often disturbance adapted (Fox & Fox 1986; Panetta & Hopkins 1991). Nutrient enrichment and reduction in toxicity due to heavy metals in newly created roadside sites can also result in high alien species richness in these sites (Barbosa *et al*. 2010).

A very high number of herbaceous plant species were found to be associated with roadsides with only a few shrubs and a single tree species. Besides, the percentage of alien species was higher among biennials and annuals than perennials. Thus, present study clearly shows that roadsides act as reservoirs of alien plant species with short life span and simple growth forms. Sullivan *et al*. (2009) also reported that life form is an important factor that determines the presence of a species along roadsides, with trees and vines unlikely to be on roadsides. It is because highly disturbed habitats, where in only a short period of time is available from juvenility to maturity, species of herbaceous nature are predominant.

Present study also revealed that the richness of alien plant species decreased as the perpendicular distance from the road increased. On the other hand, the native species richness increased as the perpendicular distance from the road increased. These results are consistent with the findings of Tyser & Worley (1992) who reported that exotic species richness was nearly twice as great along roadside edges compared to 25 m from roads in grasslands of Glacier National Park (USA). Further, the percent cover of exotic species was significantly greater at 10 m and 100 m from roads than at 1000 m from roads in central California (Gelbard & Harrison 2003). Similar results have been reported for the Chequamegon National Forest (northern Wisconsin) (Watkins *et al*. 2003) and the Quail Ridge Reserve (Napa County, California) (Harrison *et al*. 2002).

The present study indicates an increase in average abundance of native species with increase in the perpendicular distance from the road. On the other hand, the variation in the average

abundance of alien plant species was found to be inconsistent with the perpendicular distance from the road. The main reason for this pattern could be that the expansion of a population is channeled along the road by failure of establishment away from the road (Christen & Matlack 2006), although seed dispersal occurs equally in all directions. This results in a higher abundance of alien species close to the road. Decrease in abundance of alien species and increase in abundance of native species with distance from the road were also reported by Barbosa *et al*. (2010).

These observations assume significance particularly in view of the promotion of Kashmir valley as a tourist destination, as construction of roads and railway lines will spread alien plant species to ever greater ranges. Hence creation of tourism infrastructure particularly construction of roads is likely to put the ecosystems of the region at higher risk of invasion.

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