Botanical Studies (2009) 50: 217-227.

Patterns of plant invasions in the preserves and recreation areas of Shei-Pa National Park in Taiwan

Shan-Huah WU [1], J. K. TSAI[2], H. T. SUN [2], C. F. CHEN[2], and Chyi-Rong CHIOU[3,]*

[1]Biodiversity Research Center, Academia Sinica, 128, Sec. 2, Academia Rd., Taipei 115 Taiwan
[2]Department Life Science, National Taiwan Normal University, 88 Sec. 4, Ting-Chow Rd., Taipei 116, Taiwan
[3]Department Forestry, National Taiwan University, 1, Sec. 4, Roosevelt Rd., Taipei 106, Taiwan

(Received June 25, 2008; Accepted November 27, 2008)

ABSTRACT. Nature preserves in the national parks are usually adjacent to the recreation areas, where most of the tourists visit. Although permits are required and only few small trials are available to enter the preserves, species naturalized in the neighboring recreation areas may hitchhike across the borders. To estimate the differences of plant invasions in neighboring preserves and recreation areas experiencing different intensity of anthropogenic activities, we employed Wuling district (alt. 1,800-3,860 m), Shei-Pa National Park in Taiwan as our study site. Our hypotheses were: (1) the recreation areas harbor more naturalized species, and plant invasion patterns are different in these areas under various land management strategies; (2) species inhabiting the preserves could be found in the recreation areas as well; (3) naturalized species of temperate origins are dominant due to the temperate weather in the mountains. Total of 230 quadrats in one meter square quadrats were randomly selected along the roads and trails in both areas. Naturalized species, relative cover, elevation, and naturalness degree were obtained and analyzed. The results showed that the naturalized species in both areas were herbaceous, originating from tropical and temperate Americas and Europe. Naturalized floras of these two areas were presented by analogous dominant families, Asteraceae and Poaceae, and dominant species, *Bromus catharticus* and *Trifolium repens.* However, the number and coverage of naturalized species, α diversity, elevation, and naturalness degree, suggested different patterns of plant invasions of these two areas. Recreation areas accommodated significantly more naturalized species and higher coverage, and elevation was responsible for distinct patterns of plant invasions. Both of the preserves and recreation areas in Wuling provided suitable habitats for similar naturalized floras; however, relatively more species harbored by the later implied a source and sink relationships between these two areas. Furthermore, environmental factors that change with the elevation, such as temperature, topography, and native vegetation, may contribute to different patterns of plant invasions presented by preserves and the recreation areas in the subtropical mountains.

Keywords: National park; Naturalized species; Nature preserve; Plant invasions; Recreation area; Shei-Pa National Park.

INTRODUCTION

Invasive species have been considered as major threats to the ecosystems of national parks by altering the soil nutrients, taking over territories, forming monocultures, changing species compositions, etc (Rogers and Leathwick, 1996; Wuerthner, 1996; Jesson et al., 2000; Evans et al., 2001; Wolf et al., 2004). The way in which invasive species get into these native habitats are rarely discussed (Gelbard and Harrison, 2005; Foxcroft et al., 2007, 2008). Human activity may be to blame (Larson et al., 2001). We believe that the recreation function of national parks brings people to appreciate natural wonders, but also increases chances of possible invasions, since land use intensity has been contributive to plant invasions in both recreation and protected areas of national parks (Mckinney, 2002; Foxcroft et al., 2007). Although the disturbance caused by visitors and transportation infrastructures is mostly concentrated in the designated recreation areas, these areas may serve as a base for invaders to expand their territories into adjacent protected areas, nature preserves, and cause problems (Wein et al., 1992). Despite the endeavors scientists have devoted to estimating plant invasions in national parks (Schwarz and Wein, 1997; Jesson et al., 2000; Rowlands and Brian, 2001; Pauchard et al., 2003; Foxcroft et al., 2007, 2008), patterns of plant invasions in neighboring recreation and protected areas with different anthropogenic disturbances are seldom reported.

*Corresponding author: E-mail: esclove@ntu.edu.tw; +886-2-33664640; +886-2-23697658.

According to Pyšek et al. (2004), many environmental and biological barriers have to be conquered for an introduced species to invade new territories successfully. Environmental factors, such as disturbance, usually provide more opportunities for successful invasions (Ross et al., 2002; Hendrickson et al., 2005; Alston and Richardson, 2006). However, disturbance could be an environmental barrier for introduced species to invade places with low intensity of anthropogenic activities or pressures of natural disturbances (Kang et al., 2007; Paiaro et al., 2007; Theoharides and Dukes, 2007). On the other hand, the invaders' successful establishment and spreading may depend upon other factors as well, such as biological traits and climates (Wu et al., 2004b; Thuiller et al., 2006; Wilson et al., 2007). We assumed that alien species successfully establishing in native habitats might be considered as respective competitors and deserve attentions. Besides, patterns of plant invasions in the preserves might generate better understanding of invasiveness.

The compositions of naturalized flora and dominant naturalized species seemed to vary along the elevation gradients in the central mountains in Taiwan (Wu et al., unpublished). Our previous study (Wu et al., 2004b) suggested that dominant tropical American species in the naturalized flora of Taiwan might be a result of similar tropical and subtropical climates. Besides, noticeable amount of temperate species from Europe might find suitable habitats in the mountains where national parks and natural reserves are located. This is worrisome since these montane preserves with temperate to alpine climates are usually immediately adjacent to the recreation areas, and impacts of invasive species in natural reserves have been shown in the boreal ecosystems (Pauchard et al., 2003; Rose and Hermanutz, 2004). However, basic information about plant invasions in these areas is anecdotal.

Shei-Pa National Park is a unique and popular national park with 51 mountain peaks over 3,000 meters in elevation located in northern Taiwan. The undulated topography changing from about 1,000 to 3,886 meters, together with climate variations, result in the diversified habitats of Shei-Pa National Park harboring 61 endemic and rare flora, such as Taiwan Sassafras (*Sassafras randaiense*), Devol's Balsamine (*Impatiens devolii*), *Dumasia miaoliensis*, *Epilobium nankotaizanens,* and fauna, like Formosan Black Bear (*Selenarctos tibetanus formosanus*), Formosan Macaque (*Macaca cyclopsis* Swinhoe), Formosan Land-locked Salmon (*Oncorhynchus masou formosanus*), Mikado Pheasant (*Syrmaticus mikado*),and Swinhoe's Blue Pheasant (*Lophura swinhoii*) (Wang, 1995). Despite its remote location and frequent landslides on the main entrance ways, the major district of Shei-Pa National Park, Wuling, is one of the most popular destinations to the public and the most developed area compared to other districts of this national park. A five star resort, few hotels, vegetable farms, fruit and tea plantations are the dominant scenes of this region. These crop fields and plantations are directly adjacent to the preserves and right on the side of Cijiawan Creek, the home of endangered landlocked salmon, endemic *Oncorhynchus masou formosanum* (Tseng, 1999). There is no restriction for visitors to enter the recreation area, while permits are required for accessing the neighboring preserves. The trail and cabin system is well established in Wuling district, which leads backpackers to the mountain peaks deep inside the preserves from the recreation areas, in which the ranger stations situated. In summer, the mountaineering season, the cabins are usually full of hundreds of people during holidays and long weekends. We were concerned that invasive species may hitchhike into the roadless nature preserves along the trails by mountain hikers (Harrison et al., 2002).

Abandoned fields are becoming common recently in the recreation areas in Wuling, and naturalized species are usually seen and dominant in these fields. Following the act of retreating farms and fruit plantations out of the national park in recent years, many abandoned farms have been scattering in the recreation areas of Wuling. Although some of these fields are still under certain levels of farming, the grounds are usually occupied by naturalized species and persistent crops. Besides, the groundcover of less managed fruit plantations is usually a mixture of naturalized and native herbaceous species. Landslides and disturbances of different intensities caused by frequent visiting typhoons may also exacerbate plant invasions since naturalized species usually favor disturbed areas and they may get into the neighboring preserves by edge effects (Lu and Keping, 2006).

The main purpose of our study was to approach and compare the patterns of plant invasions in both preserves and recreation areas, which represented two different intensities of land management and use, in the Wuling district of the Shei-Pa National Park. We hypothesized that (1) the recreation areas should harbor more naturalized flora, and plant invasion patterns are different in these areas under various land management strategies; (2) species inhabiting the preserves could be found in the recreation areas as well; (3) naturalized species of temperate origins are dominant due to the temperate weather in the mountains. The field investigation was conducted in summer, 2006.

MATERIALS AND METHODS

Study site

We chose Wuling district of Shei-Pa National Park (24°23'15.6" N latitude, 121°18'08.0" E longitude) (Figure 1) for this study, since it is the only district with accessible nature preserves and recreation areas experiencing different levels of anthropogenic activities. Shei-Pa National Park is located in northern Taiwan, and Wuling is in the east of this national park with conservation areas, special scenic areas, general protected areas, and recreation areas. We grouped these four types of areas into

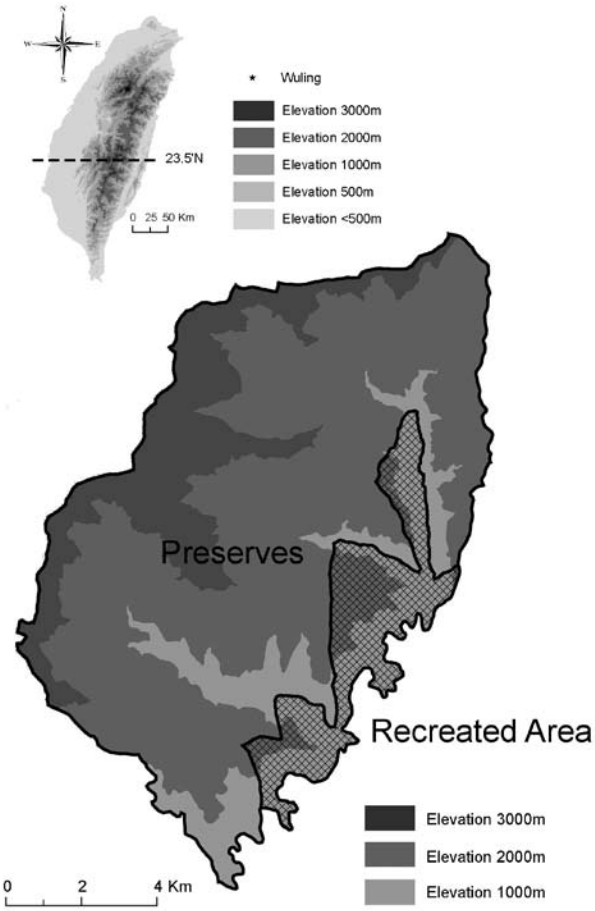

Figure 1. Location and topography of the study site, Wuling, Shei-Pa National Park, Taiwan (24°23'15.6" N latitude, 121° 18'08.0" E longitude).

two major categories, recreation areas (general protected and recreation areas) and preserves (conservation and special scenic areas) for our study based on their land management types.

The recreation areas are relatively smaller than adjacent preserves possess major attractions and host majority of the visitors. Elevations the preserves are approximately 1,800 to 3,850 meters. Annual average temperature is about 16°C and the annual average precipitation is about 2,200 mm (Wang, 1995; Ou et al., 2006). The vegetations of the recreation areas are gardens, abandoned fields, vegetable farms, tea plantations, temperate cloud forests (*Quercus* forests and *Tsuga-Picea* forests), and riparian. The preserves are mainly covered by temperate cloud forests, conifer forests, alpine grasslands, and *Abies* woodlands (Hsieh et al., 1997). The alpine grassland, the dominant vegetation over 3,000 meters in elevation, is composed of very short bamboo, *Yushania niitakayamensis* (Hayata) Keng f. (Wang, 1995).

The transportation system in the recreation area is simply one county road together with a few outlets. Only hiking trails lead to the preserves. The entrances of these hiking trails to the preserves, however, are usually at the ends of the outlets extending from the recreation areas. No restriction is applied for entering the recreation areas, while passes are required to approach the preserves.

Materials

To access the patterns of plant invasions, naturalized species were utilized to present potential invaders, since naturalization is the fundamental step for an introduced species to invade new territories (Pyšek et al., 2004). Wu et al. (2004a) was employed for identifying naturalized species. Since the list was published a few years before the study, relevant journal publications were also used as supplementary.

Methods

Random sampling was implemented in this study for plot selection. Approximately ten quadrates of 1 × 1 square meter were randomly selected in every kilometer along the roads and trails in both the recreation areas and preserves. The distances of the quadrats to the roads ranged from one to ten meters according to random number table. For each quadrat, species and relative coverage (%) of naturalized species were recorded. Furthermore, environmental factors, including degree of naturalness, vegetation type, and elevation were collected. Naturalness degree simply classifies habitats into six levels according to the vegetation types and anthropogenic utilizations: level five represents native forests, four for native grasslands, three for timber plantations, two for croplands and fruit plantations, one for bare grounds, and zero indicates constructions and infrastructure (Huang et al., 1999).

Data obtained in the field were complied and analyzed for preservers (P) and recreation areas (R) for comparisons. Simple statistics was performed to summarize basic numerical data, such as numbers of family, genus, and species. Additionally, abundance was estimated by the total relative coverage (%) of each naturalized species, and relative frequency was calculated by the percentage of total plots divided by present plots. IVI (Importance value index) values of naturalized species were estimated by half of the sum of relative abundance and relative frequency. Species with the highest abundance and IVI value were both considered as the dominant species. As for the origins, life forms and habit of most naturalized species, we referred to Wu et al. (2004a).

Total coverage of naturalized species (SUM), number of naturalized species (N), and six α diversity indices, including Shannon-Wiener index (H'), Simpson (λ), evenness (E5) (Ludwig and Reynolds, 1988), species richness (N1) and Berger-Parker dominance (BP Index) (May, 1975) of each plot with naturalized species in protected and recreation areas were calculated by SDR (Species Diversity and Richness 4.1.2, 2006). A total of 230 plots were included, and obtained field data were separated into two sets: one set for preserves; the other for recreation areas, for further analysis. Multivariate Analysis (MANOVA) was performed, and $P<0.05$ was used to determine the significance in all tests. Factor analysis (FA) was also utilized to visualize and group the patterns of the indices. Regression tree analysis was employed to access the most significant variables separating patterns of plant invasions in protected and recreation areas. Proportion of reduction error (PRE) value, similar to R^2 in regression, was used to determine the amount of variation explained by the independent variable (Hansen et al., 1996). Factor Analysis (FA), Multivariate Analysis (MANOVA), and regression tree analysis performed by SYSTAT (version 11.0, Systat software Inc., Richmond, CA, USA. 2004).

RESULTS

The biological composition and biodiversity indices differed between the preserves and recreation areas (Table 1). About 40% of the plots in the preserves did not have any naturalized species, while around 10% of the plots in the recreation areas were free of naturalized species. Five biodiversity indices of these two areas were significantly different, and two environmental factors, such as elevation and naturalness degree, also showed significant difference for the preserves and recreation areas (Table 1). All of the

Table 1. Numerical summary of plots, species composition, life forms, coverage (%), and α diversity indices of protected and recreation areas. Summary statistics (mean with standard error in parentheses) by species number, coverage (%), α diversity indices, and environmental factors are included.

	Protected areas	Recreation areas
Plot number	107	163
Plot with naturalized plant	83	147
Plot without naturalized plant	24	16
Family number	10	12
Genus number	16	25
Species number	21	32
Vine	0	1
Herbaceous	19	29
Shrubs	2	2
Trees	0	0
Dominant species	*Bromus catharticus*	*Bromus catharticus*
	Trifolium repens	*Trifolium repens*
Dominant family	Asteraceae	Asteraceae
Dominant genus	*Bidens*	*Bidens*
Species number/plot	1.55 (0.11)	2.43 (0.09)****
Coverage sum (%)	1556.5 (15.565 m^2)	5366 (53.66 m^2)****
Maximum cover (%)	15.92 (2.80)	27.95 (2.10)****
Mean cover/plot (%)	18.76 (3.38)	36.50 (2.54)
Shannon-Weiner Index (H')	0.25 (0.04)	0.53 (0.03)****
Simpson Index (λ)	1.40 (0.09)	1.80 (0.06)***
Evenness (E5)	0.95 (0.03)	0.81 (0.02)****
Richness (N1)	1.37 (0.07)	1.84 (0.06)****
Berger-Parker dominance Index	0.87 (0.02)	0.76 (0.02)****
Elevation (m)	2148.22 (30.00)	1848.72 (22.54)****
Naturalness degree	3.02 (0.14)	4.39 (0.11)****

MANOVA: n = 270. Means with asterisks are significant from each other of the value of protected and recreation areas.
***: $P<0.001$; ****: $P < 0.0001$.

naturalized species were herbaceous and shrub in both areas; no naturalized trees were found (Table 1).

In terms of naturalized flora, the recreation areas tended to harbor more families, genera, and species. However, the dominant species *Trifolium repen* L. and *Bromus catharticus*, followed by *Conyza sumatranesis*, and *Bidens pilosa* var. *pilosa* were the same for these two types of habitats (Table 2). The dominant family was Asteraceae followed by Poaceae and Fabaceae for both areas (Figure 2A). Most of the naturalized species in both preserves and recreation areas originating from tropical and temperate regions, especially the Americas and Europe (Figure 2B).

The first two factors of factor analysis explained about 71% of the total variance (Figure 3A). Indices related to the numbers of naturalized species, such as H' and λ, were on the positive end of the first factor, while BP index was on the opposite end. For factor two, elevation and total coverage of the naturalized species were on the positive end while naturalness degree and evenness (E5) were on the other side. Regression tree analysis showed that elevation was the most significant variable distinguishing the patterns of plant invasions of preserves and recreation areas in (PRE = 0.72) (Figure 3B).

DISCUSSION

Plant invasions seem to be moderate in the Wuling district. Compared to the 1,135 native species in this region (Hsu, 1984), naturalized species only represented a very small portion, approximate 4% of the total flora, half of that of the whole island (about 8% of the Taiwan flora is naturalized (Wu et al., 2004a). The difference might be the results of geographical isolation or the climates of this district. Situated in the central ridge of Taiwan, the only one county road leading to this region is usually damaged by frequent typhoons in summer. Besides, nearest city connected by this only one wavy road is in about three-hour driving distance. On the other hand, snows falling on the mountains and harsh freezing winter in this region might screen out the majority of naturalized species, which dominant in the lowlands, from the tropics. Although the proportion presented by naturalized species was small, it

Table 2. Top ten dominant species of protected and recreation areas. Plant taxa are in the order of IVI values from high to low. The family species belongs is indicated in parentheses. Both of the species with the highest IVI and relative cover (%) are considered as dominant species with bolded numbers of IVI and relative cover (%).

Species (Family)	IVI	Relative cover (%)
Recreation areas		
Bromus catharticus Vahl. (Poaceae)	**23.42**	12.26
Trifolium repens L. (Fabaceae)	20.90	**14.92**
Conyza sumatrensis (Retz.) Walker (Asteraceae)	10.72	4.39
Bidens pilosa L. var. *radiata* Sch. (Asteraceae)	9.41	4.11
Trifolium pratense L. (Fabaceae)	3.06	2.03
Veronica persica Poir. (Scrophulariaceae)	2.98	2.41
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	1.83	0.80
Lolium multiflorum Lam. (Poaceae)	1.77	1.08
Momordica charantia L. var. *abbreviata* Ser. (Cucurbitaceae)	1.75	1.41
Lepidium virginicum L. (Brassicaceae)	1.61	1.15
Protected areas		
Bromus catharticus Vahl. (Poaceae)	**11.43**	5.87
Trifolium repens L. (Fabaceae)	10.43	**8.78**
Lolium multiflorum Lam. (Poaceae)	6.75	4.05
Conyza sumatrensis (Retz.) Walker (Asteraceae)	3.25	1.15
Bidens pilosa L. var. *minor* (Blume) Sherff (Asteraceae)	2.27	0.92
Bidens pilosa L. var. *radiata* Sch. (Asteraceae)	2.23	1.03
Crassocephalum crepidioides (Benth.) S. Moore (Asteraceae)	1.67	0.32
Trifolium dubium Sibth. (Fabaceae)	1.33	0.73
Ageratum conyzoides L. (Asteraceae)	1.11	0.81
Geranium carolinianum L. (Geraniaceae)	0.64	0.19

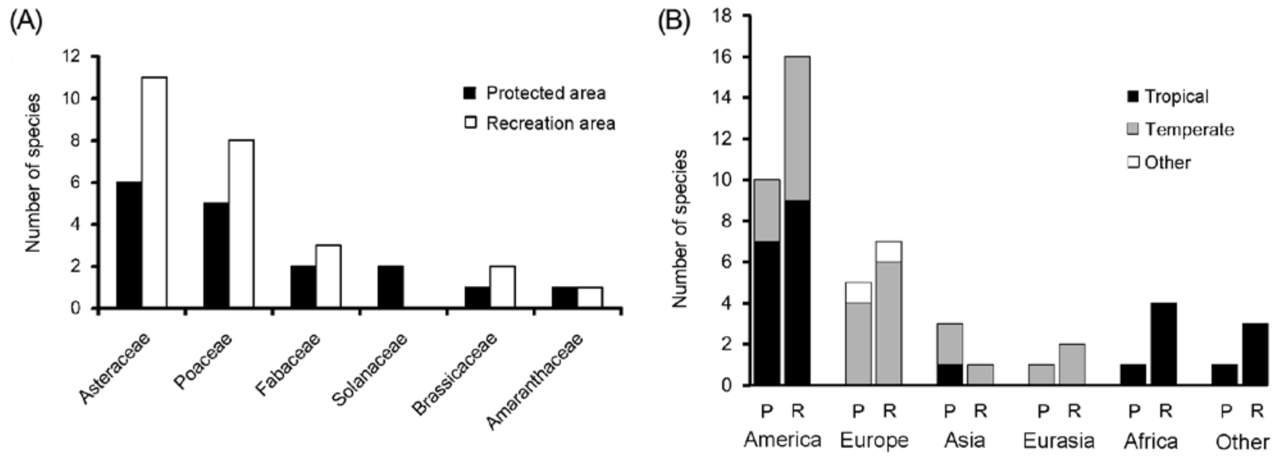

Figure 2. A, Dominant families of the naturalized flora in the protected areas and recreation areas; B, Origins of naturalized species in the protected (P) and recreation areas (R).

is very difficult to testify whether Taiwan is more resistant to plant invasion as Wu et al. assumed without supporting field data (Wu et al., 2004b; Daehler, 2006).

The same dominant family, genera, and species shared by preserves and recreation areas may be explained by neighboring and stepping stone effects. The number of naturalized species was significantly less in the preserves than in the recreation areas (Table 1), nevertheless, all the naturalized species present in the preserves were in the flora of recreation areas. This, furthermore, supported our idea that the naturalized flora of the protected areas is a fraction of the naturalized flora in the recreation areas. Besides, this result also implied that naturalized species may come from the neighboring recreation areas where tourists stop by before visiting the preserves. These shared species should have broader niche breadth (Richards et al., 2006).

The dominant species, *Trifolium repens*, and *Bromus catharticus* Vahl (Table 2), of both areas might find the temperate habitats in the central mountains of Taiwan similar to their home ranges in Europe and temperate South America (Richardson and Thuiller, 2007). Although the nitrogen fixing function of *T. repens* may alter soil nutrient gradients (Warren, 2000; Evans et al., 2001), its impacts were restricted since it was currently only present in places located in relatively developed areas. On the contrary, *B. catharticus*, the only species surviving in alpine vegetations up to 3,800 meters in elevation, has

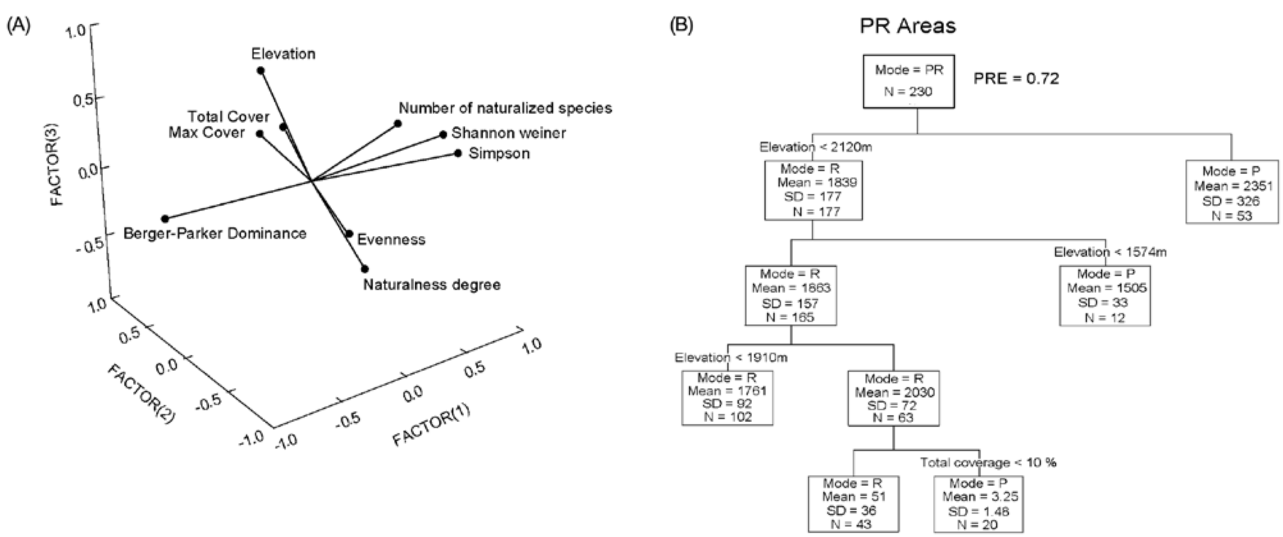

Figure 3. A, Factor analysis for number of naturalized species, total cover of naturalized species, the biodiversity indices, elevation, and naturalness degree of the protected and recreation areas. Percent of total variance explained is 42% for factor (1), 29% for factor (2), and 15% for factor (3); B, Regression tree for number of naturalized species, total cover of naturalized species, the biodiversity indices, elevation, and naturalness degree across the area types (protected and recreation areas), including means, standard deviation (SD) and sample size (n) for each break. PR areas indicated protected and recreation areas. PRE (0.72) indicates the proportion of reduction in error.

adapted very well to harsh montane environments. *Bromus catharticus* has been shown to possess various advantages in growing and population maintaining, such as high phenotypic plasticity to various environments, large seed production, seed dormancy, low temperate tolerance, and high genetic variation (Mauromicale and Cavallaro, 1996; Wolff et al., 1996; Pistorale et al., 1999; Wolff et al., 2001; Aulicino and Arturi, 2002). Beside the respectful distributions in alpine habitats of *B. catharticus*, it often formed monoculture and occupies most of the abandoned fields in the recreation areas as well. The distribution of *B. catharticus* in the preserves was, nevertheless, scattered and not continuous. More specifically, it appeared at almost every stop and cabin on the hiking trails. However, not a single individual was found in the short bamboo (*Yushania niitakayamensis*) grasslands. We suggested that the bamboo grasslands may function as a barrier (Perelman et al., 2003) for plant invasions since they did not accommodate any other naturalized species, either. Although the distribution and dominance of *B. catharticus* seemed to be threatening, we know nothing about this species unfortunately. It is very worrisome that *B. catharticus* may continue to spread and alter the alpine ecosystems in the future, because their flexibility and plasticity may be induced through interactions between local alpine environments in terms of adaptation (Mooney and Cleland, 2001). Further studies regarding its impacts and associations with native species are immediately needed. Furthermore, the possible defense mechanism of *Y. niitakayamensis* may generate better understanding of biological resistance (Chou and Yang, 1982; Eyini et al., 1989).

Compared to the naturalized flora of Taiwan, Wuling accommodated relatively more temperate species, although species originating from the tropics were still presented at certain proportions (Figure 2B). This supported our expectation that the mountain areas in Taiwan may harbor relatively more temperate species due to similar climates (Pino et al., 2005). Tropical species, such as *Conyza sumatrensis* and *Bidens pilosa* L. var. *minor* (Blume) Sherff. still deserve further attentions, since they also thrived in both preserves and recreation areas. Although warm and humid weather in summer in this area may provide suitable habitats, freezing temperate and relatively harsh environments in winter still resulted in surviving pressures to tropical species. Adaptation mechanisms of these species deserve more attentions (Parker et al., 2003).

The composition of species and α diversity indices supported our hypothesis that preserves and recreation areas, two land management types, presented different patterns of plant invasions (Table 1). It is not surprising to observe more naturalized species and total cover (SUM) of naturalized species in the recreation areas. In addition, the differences of biodiversity indices strongly suggested two different patterns of plant invasions in these two areas. Significantly higher H', and λ of recreation areas implied the composition of naturalized species was more diversified, and species coexistence was common according to E5 (Table 1). On the contrary, significantly lower evenness and higher BP index of the preserves revealed that the composition of naturalized species was relatively uneven and dominated by few species in the preserves. We suspected that different land uses and native species community were relevant to these patterns. Abandoned crop fields and plantations were the major habitats for native and naturalized species in the recreation areas, and chances for both species were assumed equal when the fields were available. Therefore, relatively even species composition could be a result of stochastic effects. On the contrary, relatively undisturbed native plant community formed by short bamboo and alpine species left scattered openings for naturalized species to stand. Only few species with formidable invasiveness could possibly establish colonies after interacting with local species and environments.

The environmental factors changing along the elevation might be the causes of different invasion patterns in the preserves and recreation areas (Figures 3A and B). The result of factor analysis implied that elevation was the factor correlated with total cover, since elevation was categorized in the same factor with total cover of the naturalized species, while the first factor of the factor analysis was basically comprised of all the variables relevant to species number. This pattern, furthermore, was confirmed by the regression tree analysis (PRE = 0.72). However, the naturalness degree, which we employed to indicate the land cover types and probable land use intensity, showed a reversed pattern (Table 1). It did not seem to be reasonable that the naturalness degree of the preserves was significantly lower than that of the recreation areas, but we suggested that was a result of certain areas of bare ground of gravels in the alpine zone, which was categorized as zero. Although species number together with a few more biodiversity indices were the major factors that separated the plant invasion patterns of the preserves and recreation areas. The most important factor resulting in these different invasion patterns was elevation (Baret et al., 2004; Becker et al., 2005; McDougall et al., 2005). Different elevations separated almost every subsets of the regression tree on the recreation area side, and we were clear that the higher the elevation, the fewer the naturalized species. This result had nothing to do with disturbance levels alone, although the land management and anthropogenic activities were definitely different in the recreation areas and preserves. However, it pointed out that the factors changing along the elevation (similar to the latitude effect), such as climate, dominant native species, dominant vegetation type, temperature, disturbance, may be important in terms of resistance (Pyšek, 1998; Cantero et al., 2003; Arevalo et al., 2005; Gelbard and Harrison, 2005; Richardson et al., 2005).

Our results basically supported all of our hypotheses, although elevation, instead of nature degree, was the factor contributing to different plant invasion patterns of plant invasions in protected and recreation areas. These different patterns of plant invasions provided valuable information of mountains in subtropical regions, where studies on plant invasions are seriously rare. However, dominance of *Bromus catharticus* in the preserves, especially in the montane ecosystems, definitely requires further ecological studies and deliberate attentions, since these habitats are home to 25% endemic species and several species which survived the last ice age (Hsieh et al., 1997). Furthermore, we suggest that monitoring systems should be established at the entrances of preserves, since few species have managed to infect the protected areas from adjacent recreation areas.

Acknowledgements. This study was sponsored by Shei-Pa National Park, Construction and Planning Agency, Ministry of the Interior, in 2006. Many thanks to park rangers and staffs for technical support and assistance. Furthermore, we thank Drs. Chang-Fu Hsieh and Chi-Jung Chiu for technical supports; Wei-Chun Cheng, Yu-Ting Chung, Chia-Long Huang, Chwen-Ling Kuo, Pei-Chun Liao, Cheng-Fan Yang, and Sheng-Jye Wu for help with fieldworks, and Hsuan-Jung Su for manuscript revision. Moreover, we are very grateful for the valuable comments and suggestions provided by two deliberate anonymous reviewers.

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雪霸國家公園相鄰之保護區與遊憩區之植物入侵趨勢比較

吳姍樺[1] 蔡正國[2] 孫豪廷[2] 陳巧芬[2] 邱祈榮[3]

[1] 中央研究院 生物多樣性研究中心
[2] 國立臺灣師範大學 生命科學系
[3] 國立台灣大學 森林環境暨資源學系

台灣國家公園的保護區，蘊含豐富的特、稀有生物，然而其面臨的植物入侵衝擊，卻少有資料可得。入侵植物傳播與擴散已被證實與人為活動及交通建設程度正向相關，而國家公園的保護區多半緊鄰人為活動頻繁的遊憩區，因此，遊客及車輛的來往，極有可能將入侵植物由國家公園外引入遊憩區，進而入侵相鄰的保護區，衝擊當地生物多樣性。為探討台灣山區國家公園內植物入侵之現況，本研究以雪霸國家公園遊客量最大的武陵地區為研究地點，於相鄰的遊憩區及保護區中隨機設置 230 個一平方公尺之調查樣區，以歸化植物為主要調查對象，進行植物入侵現況評估，並檢驗以下兩個假說 ：(1) 山區氣候因子將使溫帶引進之歸化植物較為優勢 ；(2) 因人為活動類型不同，相鄰的遊憩區及保護區將呈現不同的植物入侵趨勢及組成 ；(3) 保護區內的歸化植物，應與遊憩區之歸化植物組成相近。結果顯示，武陵地區之歸化植物佔當地全部植物種類之 4%，較全台歸化植物比例 6% 為低。優勢的科為菊科 (Asteraceae) 及禾本科 (Poaceae)；全區、保護區及遊憩區最優勢的物種皆為大扁雀麥 (*Bromus catharticus*) 及白花三葉草 (*Trifolium repens*)，保護區內的歸化物種組成為遊憩區之歸化植物組成之縮影，植物組成相似。大部分的歸化植物為草本，源自於熱帶及溫帶美洲，溫帶物種並無顯著優勢。植物入侵的模式在保護區及遊憩區不同，遊憩區歸化植物之種數、覆蓋度及多樣性指數值顯著較保護區高 ； 在保護區中，少數歸化物種優勢的情形顯著，而遊憩區之歸化植物組成均勻度較高。環境因子分析之結果顯示，海拔高度是造成植物組成不同之最重要因子。

關鍵詞 ： 植物入侵 ； 歸化植物 ； 國家公園 ； 保護區 ； 雪霸國家公園。