

富士山北西斜面の標高傾度にそった天然林における樹種の組成と多様性

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Diversity and composition of tree species in mature stands along an altitudinal gradient on Mt. Fuji

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Abstract

We report diversity and composition of trees at four sites along the Shoji Trail, northwest slope of Mt. Fuji, as a part of a project examining diversity-altitude relationships of microorganisms. We established four study sites (about 1ha/site) at altitudes of 1100 m, 1550 m, 1900 m and 2250 m in mature forests and surveyed trees (> 1.3 m in height). Forests were dominated by *Quercus-Fagus* at lower elevations, while *Abies* and *Tsuga* exclusively dominated at higher elevations. The observed pattern in tree species composition along the altitudinal gradient is typical at climax forest stages in the Pacific Ocean side of Japan. Species diversity generally decreased with altitude. Occurrence of large *Larix* and *Betula* at the highest site indicates the effect of disturbances. Primary forests are scarce and fragmented in most part of Japan. The unmanaged forests along the Shoji Trail can provide valuable fields to examine biological adaptations and responses of organisms to changing environments along an altitudinal gradient.

Key words: altitudinal gradient, composition, species diversity, temperate forests

要 旨

富士山北西斜面の精進登山道沿い天然林において、標高にそった樹木の組成と種多様性について調査した。人的攪乱の少ない天然林4地点（1100m、1550m、1900m、2250m）において約1haの調査区を設置し、毎木調査を実施した。標高の低い林分はミズナラブナの優占する落葉広葉樹林、標高の高い林分はシラビソコメツガの優占する常緑針葉樹林が分布していた。種の多様性は標高とともに減少する傾向が見られた。また森林限界付近の森林（2250m）では先駆種であるカラマツとダケカンバの高木がコメツガ林に混生しており、地域気候以外に噴火や雪崩などの攪乱の影響が現れていると考えられた。標高にそって極相林が維持されている地域は日本中でも限られており、精進登山道沿い天然林は垂直分布を用いた生態学調査を行うフィールドとして貴重である。

キーワード: 種多様性、標高傾度、冷温帯林、種組成

introduction

It is critical to understand how organisms adapt to environments and how biodiversity changes along environmental gradients in establishing proper management strategies under rapidly changing environments (Hooper et al. 2005). Altitudinal gradients are one of the most powerful tools to assess the patterns of adaptation and biodiversity changes with environments in relatively small geographical ranges (Körner 2007, Alberto et al. 2011). Thus, intact natural ecosystems spanning a substantial altitudinal gradient are of great scientific value. Unfortunately, such intact gradients are very rare due to intensive and widespread human impacts on

ecosystems.

Although urbanization and silviculture activities have decreased most natural forests in the area around Mt. Fuji, well-developed mature forests with limited human impacts still remain on the northwest slope of the mountain (Ohsawa 1984, Nakamura 1985). These unmanaged forests may provide excellent fields to explore biodiversity-altitude relationships. As a part of a project examining diversity-altitude relationships of microorganisms, we surveyed tree communities along the altitudinal gradient near the Shoji Trail on Mt. Fuji. This paper aims to describe diversity and compositions of tree species and discuss advantages and limitations of this area

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to investigate biodiversity-altitude relationships.

Methods

Study sites

The study was conducted along the Shoji trail on northwest slope of Mt. Fuji, Yamanashi Prefecture, Japan. This area has a temperate climate characterized by wet warm summers and moderately dry cool winters. Mean annual temperature and mean annual precipitation is 10.6 °C and 1577 mm, respectively, at the Weather station, Kawaguchi Lake at 992 m (35°26' N, 138°50' E). We established four 1-ha study sites at 1100 m, 1550 m, 1900 m and 2250 m above sea level (35°13' -35°15' N, 138°23' -138°25' E). All the study sites were established in closed-canopy mature forests developed on scoria deposit and least affected by human activities. Spatter and larva deposits were also observed partly at 2250 m and 1990 m sites, respectively. The upper most site at 2250 m was located just below the treeline. The 1100 m and 1550 m sites were located in Mt. Fuji Primeval Forest designated as National Heritage (Nakano et al. 2008, Nagaïke and Matsuzaki 2010). It was difficult to find less-disturbed mature forests even in this study area, especially below 1550 m, because of the large and intermixing *Abies* and *Larix* plantations. We also had difficulty in establishing study sites at finer intervals or replicate plots.

Sampling methods

Forest survey was conducted during the summer of 2011. Twenty-five circular plots with 5.0 m radius were arbitrary established within each study site. The centers of two plots were at least 10 m apart. Species and diameter of breast height (DBH; 1.3 m) of all trees (> 1.3 m height) were recorded in each plot. We also established two and one square plots (20 m × 20 m) at 1550 m (Plot A1 and Plot A2) and 2250 m (Plot B1) sites, respectively. The centers of the square plots at 1550 m were approximately 30 m apart. Species, DBH and location of all trees (> 1.3 m height) in the plots were recorded.

Data analyses

Tree data from the 25 circular plots were pooled for each site (total area of 1962.5 m²). Data from the square plots (400 m²) were individually analyzed. Basal area and density (stem count) were estimated for each species. Species richness, Shannon's diversity index ($H' = -\sum p_i(\log_e(p_i))$) and Simpson's diversity index ($D = 1 - \sum p_i^2$) were calculated for each site or plot, where p_i is the proportion of each species based on stem count or basal area.

Results

Species composition

The two sites at lower elevations were characterized as cool-temperate, broadleaf deciduous forests (Table 1). The stand at 1100 m was dominated by *Quercus crispula* (relative basal area

of 36 %) and subdominated by *Fagus japonica* (13 %) and *Carpinus tschonoskii* (10 %). The stand at 1550 m was dominated by *F. crenata* (47 %) and *Abies homolepis* (29 %) and subdominated by younger *Tilia japonica* (12 %), *Q. crispula* (3 %) and several *Acer* species (Fig. 1a, b). *Sasa (Sasamorpha borealis)* predominantly covered the forest floor at this site.

The two sites at higher elevations were characterized as subalpine coniferous forests (Table 1). *Tsuga diversifolia* (44 %) and *A. veitchii* (50 %) dominated at 1900 m site and *T. diversifolia* (74 %) and *Larix kaempferi* (23 %) dominated at 2250 m site (Fig. 1c). Seedlings of *T. diversifolia* and *A. veitchii* also occurred on the forest floor at both sites.

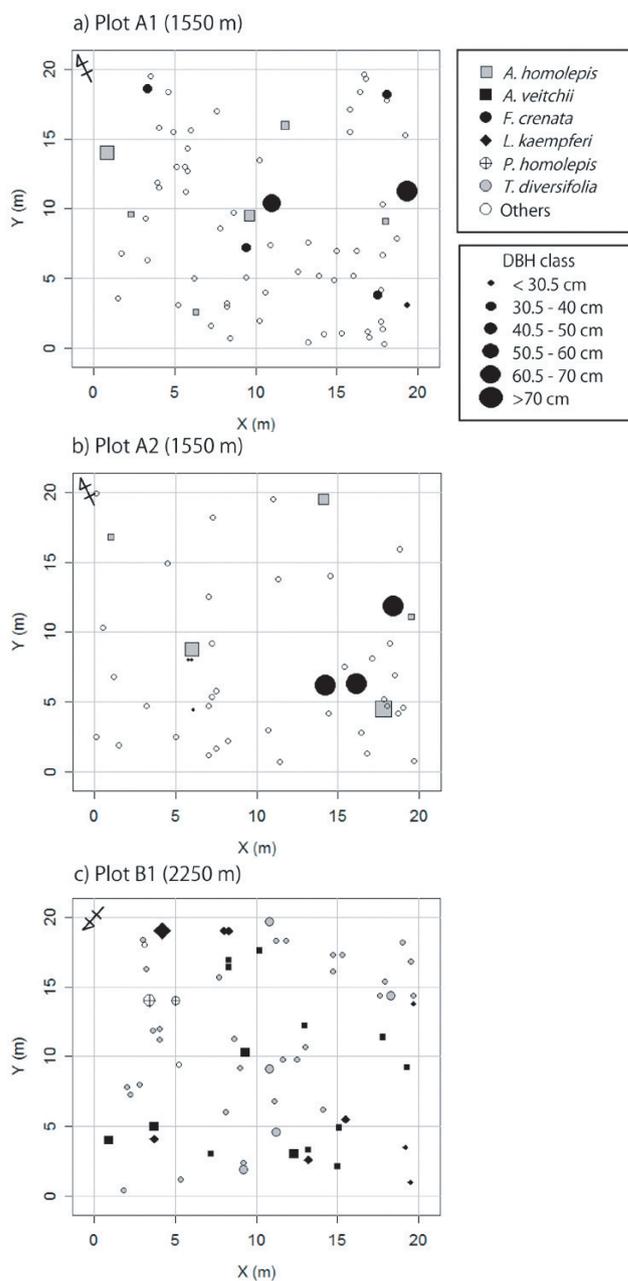


Figure 1. Spatial patterns of tree species within 20 m × 20 m plots at 1550 m and 2250 m sites. Others include species with maximum DBH < 30.5 cm.

Table 1. Stem density and basal area of tree species at each site and plot.

Family	Species	Stem Density [stems/ha]							Basal Area [m ² /ha]						
		1100m	1550m	1550m (A1)	1550m (A2)	1900m	2250m	2250m (B1)	1100m	1550m	1550m (A1)	1550m (A2)	1900m	2250m	2250m (B1)
Pinaceae	<i>Abies firma</i>	31							0.87						
	<i>Abies homolepis</i>		157	150	125					20.80	14.69	19.70			
	<i>Abies mariesii</i>					31	81	25					0.17	0.85	0.02
	<i>Abies veitchii</i>					530	188	350					24.77	2.44	14.65
	<i>Larix kaempferi</i>						183	250						21.37	26.42
	<i>Picea jezoensis</i> var. <i>hondoensis</i>		5			10				2.87			0.91		
	<i>Pinus parviflora</i>					15		50					1.99		6.28
	<i>Tsuga diversifolia</i>					876	993	900					21.65	68.81	41.26
	<i>Tsuga sieboldii</i>	20							0.06						
Cupressaceae	<i>Chamaecyparis pisifera</i>	81							2.17						
Taxaceae	<i>Torreya nucifera</i>	10							0.01						
Salicaceae	<i>Salix bakko</i>				25						1.43				
Betulaceae	<i>Betula ermanii</i>		15	25		5	50			0.46	0.64		0.15	2.45	
	<i>Betula grossa</i>	51	15	25					3.96	0.26	1.33				
	<i>Betula maximowicziana</i>	5							0.50						
	<i>Carpinus cordata</i>	367	5						1.52	0.00					
	<i>Carpinus japonica</i>		5							0.01					
	<i>Carpinus tschonoskii</i>	132							5.84						
Fagaceae	<i>Fagus crenata</i>	56	103	175	150				4.47	33.90	32.70	42.84			
	<i>Fagus japonica</i>	199							7.24						
	<i>Quercus crispula</i>	163	49	100	50				20.32	2.13	0.21	0.72			
Magnoliaceae	<i>Magnolia praecocissima</i>	10							0.15						
Cercidiphyllaceae	<i>Cercidiphyllum japonicum</i>		5						0.05						
Actinidiaceae	<i>Actinidia arguta</i>			25						0.08					
Rosaceae	<i>Pourthiaca villosa</i> var. <i>laevis</i>			50						0.03					
Rosaceae	<i>Prunus incisa</i>		5		25					0.00		0.01			
	<i>Prunus jamasakura</i>		5							0.05					
	<i>Prunus maximowiczii</i>		5							0.09					
	<i>Prunus</i> sp.	10							0.22						
	<i>Sorbus alnifolia</i>		20	25	100					0.11	0.84	1.15			
	<i>Sorbus commixta</i>		15	25						0.02	0.02				
Aceraceae	<i>Acer amoenum</i>			225	100						0.48	0.08			
	<i>Acer micranthum</i>		5							0.05					
	<i>Acer mono</i> var. <i>marmoratum</i>	143	20	25	25				3.52	0.02	0.01	0.02			
	<i>Acer nikoense</i>	46							0.36						
	<i>Acer palmatum</i> subsp. <i>amoenum</i>	107	49						1.30	0.19					
	<i>Acer rufinerve</i>	10	39	100					1.36	0.35	0.31				
	<i>Acer shirasawanum</i>	5	54	50	25				0.00	1.04	0.03	1.04			
	<i>Acer sieboldianum</i>	5	24	100					0.00	0.45	0.07				
	<i>Acer tenuifolium</i>	71	24	25					0.28	0.03	0.02				
	<i>Ilex macropoda</i>	15							0.03						
Aquifoliaceae	<i>Ilex macropoda</i>	15							0.03						
Tiliaceae	<i>Tilia japonica</i>		230	350	325				8.85	1.06	2.41				
Cornaceae	<i>Cornus controversa</i>	5	5	25	50				0.34	0.15	0.05	0.92			
	<i>Cornus kousa</i>	71							0.17						
Araliaceae	<i>Acanthopanax sciadophylloides</i>		15							0.13					
Ericaceae	<i>Pieris japonica</i>	10							0.02						
	<i>Rhododendron brachycarpum</i>					25							0.05		
Oleaceae	<i>Fraxinus langinosa</i>	15	15	25					1.36	0.02	0.01				
	<i>Fraxinus langinosa</i> f. <i>serrata</i>			275	75						0.28	0.10			
Caprifoliaceae	<i>Viburnum wrightii</i>				25						0.01				
Total		1640	886	1750	1150	1462	1477	1625	56.08	72.04	50.90	72.39	49.48	93.67	91.08

Species diversity along the altitudinal gradient

Observed species richness was 25, 25, 5 and 6 at 1100 m, 1550 m, 1900 m, and 2250 m, respectively. In the square plots, 17, 15, and 6 species were recorded in Plot A1 and Plot A2 at 1550 m and Plot B1 at 2250 m, respectively. Species richness and Shannon's diversity index based on stem count decreased sharply from 1550 m to 1900 m and slightly increased at 2250 m site (Fig. 2a). Shannon's diversity index based on basal area gradually decreased with elevation in general, although the values varied largely between circular and square plot data (Fig. 2b). Shannon's diversity index and Simpson's diversity index showed similar trends along the altitude (data not shown).

Discussion

The study stands typified climax forest types in the Pacific

Ocean side of Japan, i.e. *Quercus-Fagus* dominated broad-leaf forests at lower elevations and *Abies-Tsuga* dominated coniferous forests at higher elevations. These stands were also characterized as mature forests including relatively large diameter class trees.

Larix leptolepis and *Betula ermanii* are pioneer tree species that readily colonize disturbed sites such as volcanic deserts and avalanche slopes. They commonly occur in climax subalpine forests on Mt. Fuji as a remnant of early colonizers (Ohsawa 1984). Ohsawa (1984) suggested that *Abies-Tsuga* forests tended to replace early successional *Betula-Larix* forests with succession. We recorded large to medium diameter classes of *L. leptolepis* and *B. ermanii* in *Tsuga* dominated forest at 2250 m, but not at 1900 m site, suggesting the effect of environmental disturbance near the treeline.

Stem density, basal area (Table 1) and diversity index based on basal area (Fig. 2b) varied considerably between the circular and

square plot data at the same altitudes. Thus, the survey methods influenced the overall trend of tree diversity patterns along the altitudinal gradient. Location, shape and size of the survey area can have significant influences on results when quantifying stand characteristics (Hosoda et al. 2012). Larger survey areas would provide more general and accurate pictures; thus data obtained from our circular plot survey would be more reliable than those from the square plot survey.

Species richness and diversity were higher at lower elevations than higher elevations as reported in previous studies (i.e. Ohsawa 1984, Stevens 1992, Miyajima et al. 2007). Our results generally confirmed this diversity-altitude pattern. But the result based on stem basal area data obtained from square plots contradicted this general pattern (Fig. 2b), indicating the small survey area would be easily affected by site specific conditions and not be suitable for generalizing a diversity pattern. We also found that the stem count and basal area data resulted in different diversity-altitude relationships, i.e. the diversity index based on stem count decreased dramatically from the low-elevation deciduous to high-elevation coniferous forests (Fig. 2a) but those based on stem basal area decreased gradually with elevation (Fig. 2b). While various diversity measures are available, the selection of indices would have significant effects on results (Motz et al. 2010). Therefore, we should be cautious in selecting survey methods and diversity measures to investigate diversity patterns along the gradient.

Although we observed the decreasing tree diversity trend with altitude, hump-shaped patterns (i.e. the highest diversity occurs at mid elevation) are suggested to be the common biodiversity-altitude relationships worldwide (Lomolino 2001). Moreover, causal explanations of these patterns remain controversial (Grynes and Vetaas 2002). Data from different geographical areas and climate will likely advance our knowledge on the diversity patterns and their mechanisms. The data presented in this paper could hopefully be used in various future ecological studies concerning altitudinal gradients.

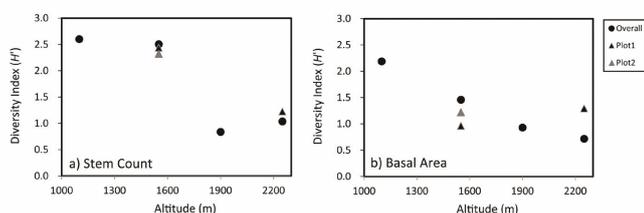


Figure 2. Shannon's diversity index (H') along the altitudinal gradient. Overall (●) represents the pooled data from 25 circular plots at each altitude.

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