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焼間と青木ヶ原溶岩流上の繁殖鳥類相の比較

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Differences in breeding avifauna between Aokigahara lava flow and a kipuka

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Abstract

Volcanic eruption is a severe natural disturbance. Thus, disturbance by lava can have indirect effects on the breeding bird community even after hundreds of years. To evaluate the effects of volcanic events on the bird community, we compared the species richness of breeding avifauna and the abundance of arthropods in two areas of Mount Fuji with different volcanic histories. Most arthropods were abundant in the kipuka, whereas only spiders were abundant on the lava flow. Furthermore, birds that described to eat spiders tended to breed on the lava flow. We also observed a relationship between bird-nesting sites and breeding area. In particular, the nesting probability of ground and rock nesters is limited by eruption products. Our findings suggest that the lava flow has effects on food availability and on nest-site availability of birds.

要　約

噴火は激しい自然攪乱であるため，数百年の後にも間接的に生態系に影響を与えている可能性がある。過去の噴火が現在の生態系に及ぼす影響を検討するために，富士山の青木ヶ原溶岩流上と周辺の焼間とで繁殖鳥類相と無脊椎動物の個体数を比較した。全体として無脊椎動物は焼間で多かったが，クモ類のみは溶岩流上に多い傾向が認められた。さらに，溶岩流上のみで繁殖が観察された鳥類は全種がクモ類を採餌する種であった。また，地上営巣性の鳥類は焼間のみで繁殖が確認され，地表面の攪乱によって営巣環境を制限されていると考えられた。これらの結果は，過去の噴火が餌資源と営巣環境という二つの面で現在の繁殖鳥類相に影響することを示唆する。

Key words：Arthropod, Bird community, Food abundance, Lava, Nest location

INTRODUCTION

Volcanic eruption is one of the most severe natural disturbances (White 1979), and can affect species' ecology depending on its type, extent, and frequency (Fridriksson and Magnusson 1992; del Moral and Grishin 1999). Many vegetation studies have evaluated volcanic succession; however, little is known about the effects of volcanic eruptions on bird populations (Dalsgaard et al. 2007). Evidence of direct volcanic impacts on forest birds is available with regard to the eruptions of Mount St. Helens (Butcher 1981; Hayward et al. 1982; Andersen and MacMahon 1986; Manuwal et al. 1987), Miyakejima Island (Kato and Higuchi 2003), and Montserrat (Dalsgaard et al. 2007). These studies have demonstrated a decline in the bird population immediately after the volcanic impact (i.e., death by ashfall, hot volcanic gas, lateral blast, pyroclastic flow, and lava). In addition to these direct effects, volcanic eruptions can indirectly affect birds; however, indirect effects have not been elucidated. For example, by scorching trees (Manuwal et al. 1987) and strongly disturbing land surfaces, volcanic eruptions can limit bird's nesting probability. The food abundance for birds may also be limited by differences created by the lava matrix, due to the lack of soil which insects hatch from and the instantaneous occurrence of markedly different vegetation types (Tisdale et al. 1965; Kamijo and Okutomi 1995; Tsuyuzaki et al. 1997). The evaluation of the effects of volcanic events on bird communities will facilitate an understanding of the adaption of birds in volcanic regions.

In the present study, we focused on two adjoining, previously disturbed areas on the largest active volcano in Japan, Mount Fuji. The first was an Aokigahara

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basaltic lava flow, which was established in 824-826 A.D. (Chiba et al. 2007). The second was a large forest fragment created by a lava flow (kipuka) between 1390-1120 B.C. (Ishizuka et al. 2007) and surrounded by the younger Aokigahara basaltic lava flow. We studied the breeding locations of bird species and arthropods abundance in the kipuka and on the younger lava flow to describe the effect prior eruption on previous ecosystems.

STUDY AREA AND METHODS

Study area.---Data were collected in the Fuji Primitive Forest (35°27′ N, 138°38′ E, 40ha, 1140m a.s.l.; average annual rainfall 1568.1 mm; annual mean temperature 10.6 °C). The Aokigahara lava flow was created by the largest volcanic eruption of Mount Fuji in 824-826 A.D., with a total eruptive volume estimated to be more than 1.2 ㎦ (Chiba et al. 2007). Most of the surface is similar to that of pahoehoe or rough pahoehoe lava in Hawaii (Takahashi et al. 2004), and the soil has only a shallow A_0 layer (Wu et al. 1989). On the lava flow, the evergreen coniferous forests are dominated by mature Japanese cypress (*Chamaecyparis obtusa*) and Japanese hemlock (*Tsuga sieboldii*). The scoria cone in the kipuka was established in 1390-1120 B.C. (Ishida et al. 2007), and was not affected by the volcanic eruption in 824-826 B.C. It has a more abundant soil layer than the lava flow (Wu et al. 1989) and a smooth land surface. The deciduous broadleaved forests in the kipuka are dominated by mature Japanese oak (*Quercus crispula*), Beech (*Fagus crenata*), and Japanese beech (*F. japonica*). Both types of forest have no understory vegetation; instead, the surface is covered solely by dead leaves and mosses.

Sampling arthropods.---We used a white nylon insect net (diameter 60 cm) to capture arthropods on leaves and branches at a height of 3-4 m, once in a week, from the 3rd of May to the 3rd of July 2009. The branches were enclosed within the net and shaken for 30minutes to remove arthropods. Trials were conducted on sunny and cloudy days but never in the rain. Using this method we were able to capture flightless arthropods. In addition, we used six malaise traps (Hoga Products; 1.8x1.6x1.1 m) made from white nylon and using a 500-ml polyethylene bottle containing 200 ml of 30% propylene glycol to capture flying insects. We hanged the traps at 2m to avoid capturing ground dwelling arthropods. Three of the traps were placed in the kipuka and three on the lava substrate. We collected arthropods approximately once a week, from April 25th to July 4th 2009. All traps were placed 30 m apart, with the entrances facing NNW, i.e., the same direction as the afternoon wind flow. All trapped arthropods were saturated with 70% alcohol and sorted to the level of order in the laboratory.

Breeding bird.--- The field study was carried out more than six hours per day starting at sunrise, more than five times per week from April 24th to August 1st 2009 and 2010. To determine the breeding bird species on two areas, we recorded the breeding activity of birds (entering cavities, carrying nest materials, or seen carrying invertebrates,) and the fledglings which were fed by parents. We estimated the bird species observed the breeding activity was the breeding birds on the area. All bird species were classified according to their food habits (insects, spiders, earthworms, seeds, plants, carnivorous) and nesting locations (ground, rock, wood cavity, tree branch), following Nakamura and Nakamura (1995), Higuchi et al. (1997), and the JAVIAN database (Takagawa et al. 2011).

Statistical analysis.---Statistical procedures followed the formulae given in R.2.12.2. (R Development Core Team 2009). To analyze the difference in arthropod abundance as captured by insect nets, we used a generalized additive model (GAM, Poisson dispersion, log link). We used the“gam”of the“mgcv”package in R, with study date (smoothed Julian date from May 3rd) and study area (kipuka or lava flow) as the explanatory variables. We smoothed the study date to control for arthropod's seasonality. Significant P values for each factor were obtained from the likelihood chi-square test of full models. Malaise traps are usable in all types of weather (Gressitt and Gressitt 1962); however, the abundance of flying insects is dependent on the weather and climatic conditions (Cooksey and Barton 1981; Briers et al. 2003). Therefore, we included in our analysis the mean rainfall and mean hours of sunlight, using data for the duration of each trap setting, obtained from the Japan Meteorological Agency database (http://www.jma.go.jp/jma/menu/report.html). To analyze the difference in arthropod abundance as captured by malaise traps, we used the generalized additive model (GAM, Poisson dispersion, log link), with study date (smoothed Julian date from May 3rd), study area (kipuka or lava flow), mean rainfall, and mean hours of sunlight as explanatory variables. We included days from before one sampling to the next as offset, to standardize the difference in duration of trap setting, and obtained significant P values from the chi-square likelihood test of the full model.

RESULTS

1）Differences in arthropod abundance between the kipuka and lava flow

When an insect net was used to capture arthropods, Lepidoptera were significantly more abundant in the

Table 1. Differences in insect abundance between study areas (kipuka and lava flow) for insects captured by nets

Order	Lava flow estimate (*P*)[a]	Smoothed Julian date (*P*)
Dermaptera	-129.7 (1.000)	0.862
Hemiptera	-0.014 (0.867)	**<0.001**
Lepidoptera	**-1.145 (0.008)**	0.065
Hymenoptera	-1.946 (0.068)	0.890
Formicidae	-0.337 (0.416)	**0.014**
Phasmatodea	-135.9 (1.000)	0.251
Araneae	**0.302 (<0.001)**	**<0.001**
Opiliones	-0.025 (0.912)	**<0.001**
Orthoptera	0.363 (0.265)	0.055
Ephemeroptera	-0.047 (0.829)	**<0.001**
Coleoptera	-0.002 (0.974)	**<0.001**

[a]Lava flow estimates indicate relative numbers compared to the kipuka in the generalized additive model (GAM; Poisson dispersion; only the Julian date is smoothed). Significant P values were obtained from the likelihood test of full models. All bold type means the variables significantly affect the arthropod abundances.

Table 2. Differences in insect abundance between study areas (Kipuka and lava flow), for insects captured by malaise traps.

Order	Lava flow estimate (*P*)[a]	Mean rainfall estimate (*P*)	Hours of sunlight estimate (*P*)	Smoothed Julian date (*P*)
Diptera	**-0.685 (<0.001)**	**-0.019 (0.038)**	0.012 (0.768)	**<0.001**
Hemiptera	0.049 (0.384)	0.019 (0.623)	0.130 (0.443)	**<0.001**
Lepidoptera	**-0.748 (<0.001)**	-0.018 (0.478)	-0.213 (0.082)	**<0.001**
Hymenoptera	**-1.112 (<0.001)**	-0.020 (0.472)	-0.014 (0.910)	**<0.001**
Coleoptera	**-0.614 (<0.001)**	**-0.021 (0.002)**	-0.013 (0.689)	**<0.001**

[a]Lava flow estimates indicate relative numbers compared to the kipuka in the generalized additive model (GAM; Poisson dispersion; only the Julian date is smoothed). Significant P-values were obtained from the likelihood test of full models. All bold types mean the variables significantly affect the insect abundances.

Table 3. Breeding bird species in Fuji primitive forest. We describe only the presence / absence of bird species on lava flow and in kipuka.

Species	On lava flow	In kipuka	Food habit[a]			Nesting location[b]
			Insects	Spiders	Others	
Regulus regulus	●		●	●		T
Certhia familiaris	●		●	●		C
Troglodytes troglodytes	●		●	●		R
Aegithalos caudatus	●		●	●	Berries	T
Sphenurus sieboldii		●			Berries	T
Luscinia cyane		●	●	●		G
Turdus cardis		●	●		Earthworms	T
Anthus hodgsoni		●	●			G
Phylloscopus coronatus		●	●			G
Parus major		●	●	●	Berries, seeds	C
Picus awokera	●	●	●			C
Dendrocopos major	●	●	●	●	Berries	C
Turdus chrysolaus	●	●	●	●	Earthworms	T
Ficedula narcissina	●	●	●	●		C
Cyanoptila cyanomelana	●	●	●			T, R
Muscicapa dauurica	●	●	●			T
Parus varius	●	●	●	●	Berries, seeds	C
Parus montanus	●	●	●		Seeds	C
Parus ater	●	●	●		Seeds	C
Sitta europaea	●	●	●	●	Seeds	C

[a]Food habit and nesting location were classified following Nakamura and Nakamura (1995), and Higuchi et al. (1997).

[b]T, tree branch; C, wood cavity; R, rock; G, ground.a

kipuka than on the lava flow (Table 1). In contrast, Araneae were significantly more abundant on the lava flow than in the kipuka (Table 1). Other arthropods were abundant in the kipuka, but the numbers did not differ significantly from those on the lava flow (Table 1). Meanwhile, with the malaise trap method, Lepidoptera, Hymenoptera, Diptera, and Coleoptera were more abundant in the kipuka (Table 2), and the numbers of captured Diptera and Coleoptera were lower when the mean rainfall increased (Table 2).

２）Breeding avifauna in the kipuka and lava flow

A total of 20 bird species bred in the study area: 16 species bred in the kipuka, whereas 14 species bred on the lava flow (Table 3). Four bird species were observed only on the lava flow, and all of them were previously described as spider-eating birds, whereas birds which eat berries tended to breed in the kipuka. In addition, ground nesters bred only in the kipuka and wood-cavity and tree-branch nesters bred in both study areas (in the kipuka and the lava flow).

DISCUSSION

The results of our study suggest that prior volcanic eruption may have two types of effects on breeding avifauna, through changes in: (1) food availability and (2) nest-site availability. With regard to food availability, we recorded abundant insects and insectivorous birds in the kipuka but not on the lava flow. It is widely described that insect abundance is influenced by vegetation. In volcanic regions, the vegetation is dependent on the soil matrix, and the abundance of arthropods is likely limited by the vegetation (Kamijo and Okutomi 1995; Tsuyuzaki et al. 1997; Parmenter et al. 2005). The kipuka has broadleaf forest while the younger lava flow has stands of evergreen coniferous forest. Thus, arthropods abundance may also be influenced by vegetation. In addition, many arthropods require soil to reproduce, and thus the low abundance of arthropods on the lava flow might be a result of the lack of soil on that substrate (Parmenter et al. 2005). One group of arthropods was more abundant on the lava flow than in the kipuka-spiders. We found that the evergreen coniferous forests on the lava flow had abundant spiders, similar to coniferous forest in other regions (Forstmeier and Keßler 2001; Mizutani 2002), and bird species which were described as spider-eating tended to breed there. Spider eating birds collect more spiders for their chicks than for themselves. For example, Narcissus Flycatcher *Ficedula narcissina* and Great Tit *Parus major* gave more spiders for their chicks than for themselves in some regions (Yui 1988). We couldn't describe the birds' prey items in the site, while these informations might mean that only spider eating birds can breed in low arthropods abundant area on the lava flow.

We also found that ground nesting species nested only in the kipuka, whereas rock nesters nested only on the lava flow. Ground nesters usually build their nests in the soil or on the soil surface; therefore, the lack of soil on the lava flow might limit their breeding area. It has also been found that predation of ground nests increases in volcanically disturbed areas (Andersen and MacMahon 1986), thus there might be other reasons for the lack of ground nesters in this study. Wood-cavity and tree-branch nesters were not affected by the soil surface, because abundant wood cavities and trees were present in both areas (Y. Okahisa unpubl. data). These results suggest that the effect of eruption products on breeding avifauna differs according to nest site characteristics.

In the present study, we have described that volcanic disturbances affect insect abundance and breeding avifauna, even hundreds of years after the eruption. As is widely described, the breeding avifauna changes depending on habitat structure (Sherry and Holmes 1985), thus alternation of avian habitat would be expected to lead to dramatic and predictable changes in bird species composition and abundance patterns across disturbance-modified landscape (Swanson et al. 2005). To elucidate more detailed habitat choice and habitat use of birds on volcanic regions, additional studies are required. We hope that our findings will facilitate an understanding of the biology and ecology of birds in volcanic regions.

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