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ORIGINAL PAPER

Effects of exotic mongoose (*Herpestes javanicus*) on the native fauna of Amami-Oshima Island, southern Japan, estimated by distribution patterns along the historical gradient of mongoose invasion

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Abstract We examined the distribution patterns of native animals on Amami-Oshima Island, southern Japan, along a historical gradient of mongoose establishment and estimated the effects of mongoose on the native fauna. To assess the relative abundance of various ground-dwelling animals, we used the following four methods; sensor cameras for exotic mammals, nighttime driving census for nocturnal native vertebrates, line census for ground-dwelling lizards, and adhesive traps for arthropods. The results indicated that seven species with larger body size, including mammals, birds, reptiles, and amphibians, were rarely observed in mongoose-infested area. By contrast, medium-sized animals showed neutral relationships with mongoose establishment. Interestingly, the densities of smaller-sized animals were higher in mongoose-infested area. It could be interpreted that smaller species have increased in abundance through top-down cascades, i.e., decreases in native predators such as frogs and lizards caused by the mongoose have resulted in increases in the abundance of smaller animals. Predation pressures by mongoose and native predators may be canceled out for medium-sized animals, causing neutral responses to mongoose by these animals. This study appears to be the first example that shows the influence of mongoose on a wide variety of native animals. In addition, our findings indicate the importance of considering the food web structure of a recipient ecosystem and contribute to the prediction and assessment of ecological risks caused not only by mongoose, but also by other invasive top predators.

Keywords Amami rabbit · Biological invasion · Food webs · *Herpestes auropunctatus* · Island · Predation · Invasive predatory mammals · Nansei Islands · Small Indian mongoose · Trophic cascade

Abbreviations

ACF Road	Amami Central Forest Road
Amami Island	Amami-Oshima Island
DISTANCE	Distance from the release point of the mongoose along the Amami central forest road

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Introduction

Invasive species are widely recognized as a major cause of recent biodiversity loss (Vitousek et al. 1997; Wilcove et al. 1998; Mack et al. 2000), and are thought to be responsible for more than 20% of the recent extinctions of vertebrate species (Reid and Miller 1989). Devastation of island faunas by predatory vertebrates has been instrumental in raising awareness of the global threat to biodiversity caused by biological invasion (Elton 1958).

Even a single species of invasive top predator could exert community-wide top–down effects on islands through direct and indirect interactions (Fritts and Rodda 1998), although evidence for such events is scanty. The introduction of the small Indian mongoose (*Herpestes javanicus*; hereafter, mongoose) to islands within a ‘‘biodiversity hotspot area’’ (Myers et al. 2000) is a good example of the devastating effects that an exotic predator can have on an insular ecosystem (Courchamp et al. 2003). This mongoose, which is native to the area from the Middle East to the Malaya peninsula (e.g. Long 2003), was introduced to many tropical areas, such as the Fijian Islands, Hawaiian Islands, Mauritius, and the West Indies, in the late 1800s to control rats or poisonous snakes (e.g. Long 2003). However, because the mongoose has generalist feeding habits, it also preys on non-target, native species (Pimentel 1955; Gorman 1975; Cavallini and Serafini 1995; Vilella 1998; Abe et al. 1999), and it is now largely blamed for the historical declines and extirpations of many native species on islands (Gorman 1975; Roots 1976; Honegger 1981; Nellis and Small 1983; Nellis et al. 1984; Cheke 1987; Case and Bolger 1991; Henderson 1992). However, few studies have explicitly demonstrated the causal linkage between mongoose invasion and native species degeneration for the following reasons. Firstly, on most of the islands infested by the mongoose, biological information from before the mongoose invasion is lacking, so the cause of decline and extirpation is anecdotal. Secondly, native species that are supposed to have been threatened or extirpated by the mongoose may have been affected synergistically by other invaders or by humans, making it difficult to separate the effects of the mongoose from other factors.

In 1979, 30 mongoose were introduced to Amami-Oshima Island (hereafter Amami Island), southwestern Japan, to control a native poisonous pit viper, habu (*Trimeresurus flavoviridis*), which was a threat to local people (Tomari 1987; Sawai et al. 1999). Although the mongoose's ability to control habu is equivocal, mongoose is now established in forest that harbors a number of endemic species and subspecies and the population in 1999 was estimated to be 5,000–10,000 (Ishii 2003). Several studies have revealed that mongoose depends primarily on arthropod prey and also preys on most rare vertebrates (Abe et al. 1999; Environmental Agency et al. 2000; Yamada et al. 2000). This indicates the potential impact of mongoose on many native species. Japan Ministry of the Environment, thus, has begun an eradication project since 2000. However, there are no quantitative assessments of native species, except for a long-term study on the Amami rabbit (*Pentalagus furnessi*), which shows a decline in its distribution concurrent with the expansion of the mongoose distribution (Sugimura et al. 2000; Yamada et al. 2000).

Fortunately, the mongoose has not spread throughout the island, and there is a spatial gradation of mongoose invasion (Environmental Agency et al. 2000; Ishii 2003; Ministry of the Environment 2005; Fig. 1), which allows us to obtain information along the gradation of the strength of mongoose's effects. In addition, the ecosystem of Amami Island has suffered fewer disturbances from human activities and other invasive species compared to other mongoose-infested islands. For example, 85% of the land area of Amami Island is still covered by subtropical forest (Sugimura et al. 2003). Invasive mammalian herbivores such as feral pigs or goats, which could alter vegetation, are not present, nor are cats and dogs confirmed to be established (i.e., reproduced) in the forested area. Only the exotic black rat (*Rattus rattus*) has become established successfully in the forested area. Although many reports have shown the detrimental effects of black rats on insular fauna (e.g. Atkinson 1985; Courchamp et al. 2003), its effects on the native animals on Amami Island is apparently limited,

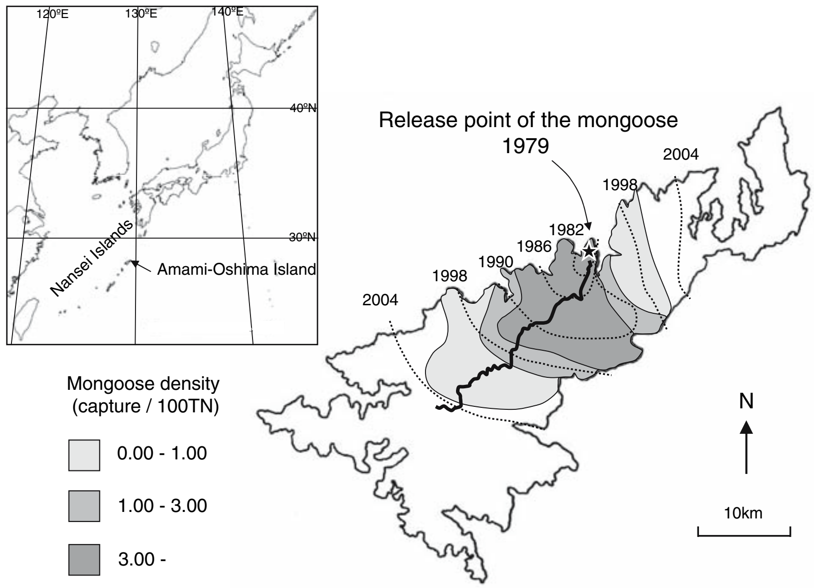

Fig. 1 Location of the Amami-Oshima Island, expansion of the mongoose distribution (dotted line) (Environmental Agency et al. 2000; Ministry of the Environment 2005), density of the mongoose (capture/100 TN) estimated by trapping conducted from 1997 to 1999 (grey gradation) (Ishii 2003), and the Amami Central Forest Road (ACF-Road) (Solid line). TN is an abbreviation of the Trap Night. The asterisk represents the release point of the mongoose

presumably because native species have evolved in the presence of two native rat species, the long-haired rat (*Diprothrix legata*) and the Amami spinous rat (*Tokudaia osimensis*). Hence, it appears that Amami Island is an ecosystem that will allow us to tease out the effects of the mongoose alone.

To do this, we examined the distribution patterns of native animals on Amami Island along a historical gradient of mongoose establishment and estimated the effects of mongoose on the native fauna. In particular, we focused on ground-dwelling animals as those likely to be affected by mongoose because the mongoose is a poor climber and its diet is composed mainly of ground-dwelling animals (Gorman 1975; Abe et al. 1999). We also investigated what traits of native animals were associated with the differential vulnerability to mongoose and explored the process causing the difference in the vulnerability.

Study area

Amami Island (28°20′ N, 129°14′ E) is the second largest island in the Nansei Islands of Japan, with an area of 712 km^2. The forest is dominated by evergreen broadleaved trees such as *Catanopsis sieboldii* and *Schima wallichii*, with a steep mountainous topography. Its climate is subtropical, with the average annual temperature and rainfall of 21.5°C and 2,914 mm, respectively.

High priority is given to the conservation of the Nansei Islands because of their high levels of endemism. The World Wide Fund for Nature (WWF) International ranks the forest of Nansei Islands as one of the world's critical or endangered terrestrial ''ecoregions'' (http://www.panda.org/about_wwf/where_we_work/ecoregions/ecoregion_list/index.cfm). The forest of Amami Island harbors a large number of the endemic species of the Nansei Islands.

Materials and methods

Study site

Our surveys were conducted along the Amami Central Forest Road (hereafter ACF-Road, 41.1 km long), which begins close to the original release point of the mongoose and leads to areas where the mongoose has not yet become established (Environmental Agency et al. 2000; Ministry of the Environment 2005; Fig. 1). Rather than using *snapshot* density of the mongoose, we used the distance from the release point as an index of the strength of its effect (hereafter DISTANCE) because the DISTANCE is expected to be negatively correlated with the *cumulative* density of the mongoose.

Assessing animals

To assess the relative abundance of various ground-dwelling animals, we used the following four methods; sensor cameras for exotic mammals, nighttime driving census for nocturnal native vertebrates, line census for ground-dwelling lizards, and adhesive traps for arthropods. These surveys were conducted from May to October, when most animals were active (Table 1).

A sensor camera (Marif Co., Ltd., Field Note) was set at each of the 27 plots that were established on the forest floor 20–80 m from ACF-Road. The distance between adjacent plots was 1.5 km (Table 1). Bait was placed around the camera, including eggs, fish sausages, dried fishes, sweet potatoes, and peanuts. We checked the cameras and bait every 2–7 days, and changed film, batteries, and bait, if necessary. This survey was conducted for 1 month.

Nighttime driving censuses were started more than 1 h after sunset. We searched for vertebrates occurring on or around the road from a car at a constant speed of about 10 km h^{-1}. We recorded species and location when we encountered vertebrates. We also recorded the call of the Amami rabbit, which is like a vocalization of the pikas (*Ochotona*) (Yamada and Fernando 2005) and distinguishable from those of other animals. These surveys were conducted four times. Data were converted to presence/absence data per 1.5 km. Small native frogs (<50 mm in snout-vent length) such as the Ryukyu brown frog (*Rana okinavana*), ornate narrow-mouthed toad (*Microhyla ornata*), and Ryukyu kajika frog (*Buergeria japonica*), which were difficult to identify from a car were recorded simply as ‘‘small frogs’’. Nighttime driving censuses focusing on smaller frogs were conducted on separate days because it was difficult to count small frogs and other animals at the same time. The frequency of occurrence per 1.5 km in the ACF-Road was calculated.

For line censuses, we established 10 additional study plots in the forest along the ACF-Road (Fig. 1, Table 1). The distance between adjacent plots was 1.6–4.6 km. Each plot consisted of a 360–1000-m line along a ridge with a gentle slope. We walked along the line at a constant speed and counted ground-dwelling lizards. The frequency of occurrence of each lizard species per 100 m was calculated for each plot.

To assess arthropods, two adhesive traps (Earth Chemical Co., Ltd., Gokiburi-Hoihoi) were placed on the ground at each of the 27 plots where sensor cameras were established (Table 1). To attract animals, we placed bait inside the traps. We checked the traps every 2–7 days and replaced them if necessary. These surveys were conducted for 1 month. Captured arthropods were counted and the capture rate of each species (individuals $trap^{-1}$ day^{-1}) was calculated.

Relationships between differential vulnerability and species' traits

To explore species' traits that likely to be associated with the vulnerability to mongoose invasion, we examined the relationships between the

Table 1 Surveys conducted and their targets, study periods, and study plots

Survey	Target	Study period	Study plot
Sensor camera	Exotic mammals	May–Jun 2003	27 plots
Nighttime driving census	Nocturnal larger vertebrates	May–Jun 2003	Entire ACF-Road[a]
	Small frogs	Oct. 2005	Entire ACF-Road[a]
Line census	Lizards	Jul. 2005	10 plots
Adhesive trap	Arthropods	May–Jun 2003	27 plots
Environmental conditions	Steepness of plot	Sep. 2003	27 plots
	Basal areas of breast height	Sep. 2003	27 plots
	Amount of litter	Sep. 2003	27 plots
	Road condition	Sep. 2003	Entire ACF-Road[a]

[a] ACF-Road: Amami Central Forest Road (41.1 km long)

distribution patterns of native animals and traits of each native animal, i.e., body weight and microhabitat in daytime. The microhabitat in daytime was categorized as ‘‘hide’’ and ‘‘exposed’’. We hypothesized that these categories may influence encounter rate or detection by the mongoose because mongoose is a diurnal hunter (Long 2003) while all native animals are mostly nocturnal (Watari personal observation). ‘‘Hide’’ means those animals using refuges in daytime such as tree cavity and underneath of dead logs, so that mongoose needs to search actively to detect them. ‘‘Exposed’’ means those animals staying on the ground or trees, or underneath of leaf litter. It seems that mongoose can easily find exposed animals because they flush or come out of litter as mongoose walks around. Traits of native animals used in this study were shown in Appendix A.

Assessing environmental conditions

To confirm that the environmental conditions of the study plots were not correlated with DISTANCE, three environmental properties were measured at each of the 27 plots where sensor cameras were established: steepness of the study plot, basal area at breast height of canopy trees, and amount of leaf litter. In addition, road conditions were surveyed over the whole range of the ACF-Road (Table 1). The amount of leaf litter was measured as the average dry weight of leaf litter (dried at 70°C for 48 h) collected from 10 30×30-cm subplots randomly located within each plot. The basal area at breast height was calculated as the total diameter at breast height (DBH) in a 30×2-m transect within each plot. The road conditions were categorized as ‘‘paved’’ and ‘‘unpaved’’.

Statistical methods

To investigate the relationships between the history of mongoose establishment and response variables obtained in this field surveys, we used the linear regression analysis for quantitative variables, and logistic regression analysis for binary variables (Table 2).

To examine the relationships between signs of regression coefficient obtained above and traits of each animal, we used Spearman’s correlation coefficient for body weight and Mann–Whitney’s *U* test for microhabitat in daytime.

Results

Records of animals

During the surveys, sensor cameras took photos of total of 4 exotic mammals. Because individual identification was difficult, we used presence/absence data at each plot. As expected, mongoose occurrence was negatively correlated with DISTANCE (Fig. 2, Table 2). Exotic black rats were found in almost all plots and their pattern of distribution was not correlated with DISTANCE (Fig. 2, Table 2). A similar tendency was found in the number of photos taken (Fig. 2, Table 2). Cats and dogs were mostly found near the release point of the mongoose (Fig. 2, Table 2).

In nighttime driving censuses, we recorded a total of 9 native vertebrates, including 2 mammals, 1 bird, 3 reptiles, and 3 amphibians (Appendix B). The locations at which vertebrates were found are shown, which were recorded in sufficient numbers to analyze their patterns (Fig. 2). The points at which the Amami rabbit, ground-nesting Amami woodcock (*Scolopax mira*), Ryukyu odd-tooth snake (*Dinodon semicarinatum*), Amami tip-nosed frog (*Rana amamiensis*), Otton frog (*Rana subaspera*), and Ishikawa’s frog (*Rana ishikawae*) were found were positively correlated with DISTANCE (Fig. 2, Table 2).

The frequency of occurrence of ‘‘small frogs’’ obtained from nighttime driving censuses showed no relationship with DISTANCE (Fig. 2, Table 2).

The frequency of occurrence of the ground-dwelling Ryukyu short-legged skink (*Ateuchosaurus pellopleurus*) observed during line censuses showed a positive relationship with DISTANCE (Fig. 2, Table 2).

Arthropods captured using adhesive traps are listed in Appendix C. Those that were thought to be attracted by captured animals were excluded

Table 2 Relationships between occurrences of animals and history of mongoose invasion (DISTANCE) estimated by regression analysis

	Common name	Scientific name	Regression analysis	Regression coefficient	P
Exotics	*Mammals*				
	Small Indian mongoose	*Herpestes javanicus*	Logistic	–0.094	**0.014**
	Black rat[a]	*Rattus rattus*	Logistic	–0.167	0.061
			Linear	0.731	0.233
	Cat	*Felis catus*	Logistic	–7.305	**<0.001**
	Dog	*Canis familiaris*	Logistic	–0.223	**0.009**
Natives	*Mammals*				
	Amami rabbit	*Pentalagus furnessi*	Logistic	0.140	**<0.001**
	Birds				
	Amami woodcock	*Scolopax mira*	Logistic	0.140	**<0.001**
	Reptiles				
	Ryukyu odd-tooth snake	*Dinodon semicarinatum*	Logistic	0.081	**0.028**
	Ryukyu short-legged skink	*Ateuchosaurus pellopleurus*	Linear	0.565	**0.032**
	Amphibians (frogs)				
	Amami tip-nosed frog	*Rana amamiensis*	Logistic	0.212	**<0.001**
	Otton frog	*Rana subaspera*	Logistic	0.125	**0.005**
	Ishikawa's frog	*Rana ishikawae*	Logistic	0.139	**0.037**
	Small frogs[b]		Linear	–0.064	0.205
	Insects				
	Camel cricket	*Diestrammena gigas*	Linear	0.002	0.195
	Yellow-spotted cricket	*Cardiodactylus novaeguineae*	Linear	–0.010	**0.003**
	Amami forest cockroach	*Episymploce amamiensis*	Linear	–0.008	**0.005**
	Satsuma small cockroach	*Margattea satsumana*	Linear	–0.002	**0.009**

Plus sign of regression coefficient indicates that the focal species occurred less frequently in areas where mongoose had established itself for a longer period. Significant *P*-values are highlighted in bold

[a] Logistic regression analysis was used for presence/absence data and linear regression analysis was used for number of photos

[b] Small frogs includes Ryukyu brown frog (*Rana okinavana*), ornate narrow-mouthed toad (*Microhyla ornata*), and Ryukyu kajika frog (*Buergeria japonica*)

(e.g. ants, bees, spiders, harvestmen, and tiger beetles). The frequencies of occurrence of 4 insect species are shown, which were captured in sufficient numbers to analyze their patterns (Fig. 2). Camel crickets (*Diestrammena gigas*) showed no relationship with DISTANCE (Fig. 2). In contrast, yellow-spotted crickets (*Cardiodactylus novaeguineae*), Amami forest cockroaches (*Episymploce amamiensis*), and Satsuma small cockroaches (*Margattea satsumana*) showed negative relationships with DISTANCE (Fig. 2, Table 2).

In summary, seven species of vertebrates showed significant decrease in occurrence closer to the original release point of the mongoose, small frogs and the camel cricket were distributed irrespective of the mongoose establishment, and three species of insects increased significantly in occurrence closer to the original release point of the mongoose.

Relationships between vulnerability to the mongoose and species' traits

Body size of native animals was correlated significantly with the vulnerability to the mongoose estimated by the regression coefficient between occurrence and DISTANCE (Spearman rank correlation: rs = 0.893, $P < 0.01$; Fig. 3), i.e., larger animals appear to be more abundant in the areas where mongoose is absent or has been established for a shorter period, whereas smaller animals show inverse patterns. However, there was no difference in the vulnerability to mongoose between "hide" and "exposed" animals (Mann–Whitney's U test, $P = 0.120$).

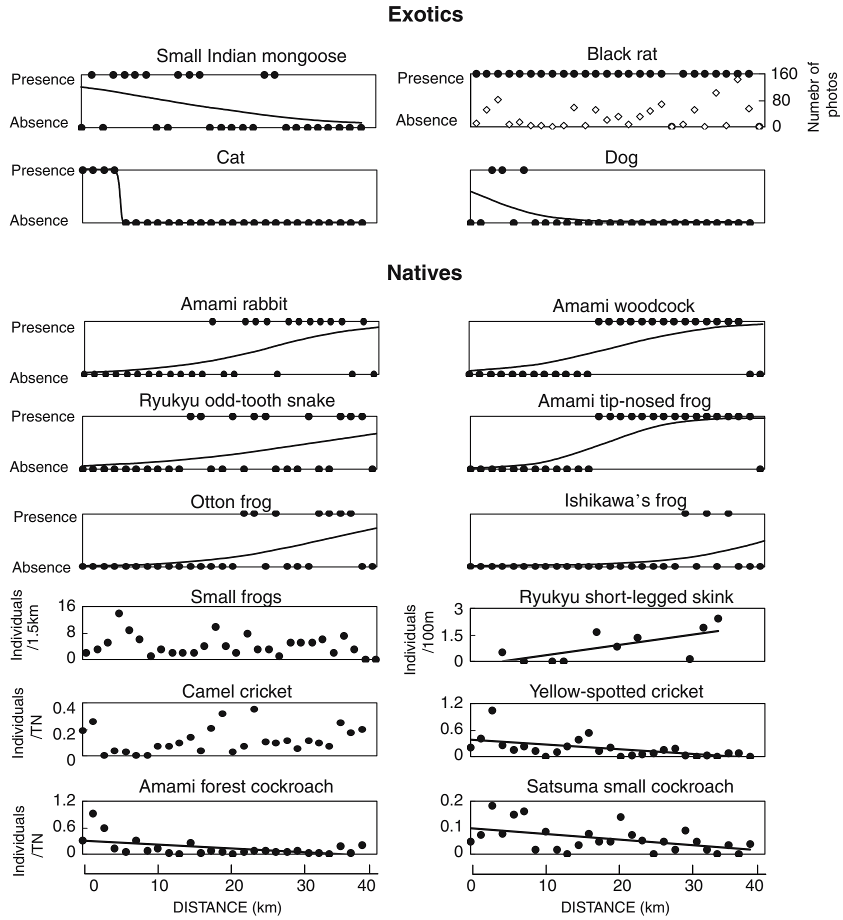

Fig. 2 Occurrence or density of animals (filled circles) and number of photos (open diamonds) along the Amami Central Forest Road (ACF-Road) estimated from surveys. DISTANCE is the distance from the release point of mongoose along the ACF-Road. TN is an abbreviation of the Trap Night

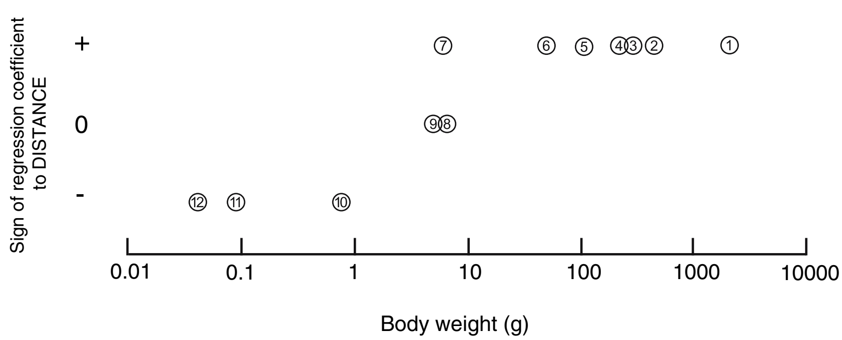

Fig. 3 Relationships between the body weight of native animals and their response to mongoose invasion. Plus, zero, and minus indicate the sign of regression coefficient of animals against the period of mongoose establishment. Numbered circles represent the following animals: 1: Amami rabbit, 2: Amami woodcock, 3: Ryukyu odd-tooth snake, 4: Otton frog, 5: Ishikawa's frog, 6: Amami tip-nosed frog, 7: Ryukyu short-legged skink, 8: small frogs, 9: camel cricket, 10: yellow-spotted cricket, 11: Amami forest cockroach, 12: Satsuma small cockroach

Environmental conditions

Regression analyses indicated that none of the four environmental parameters were related to DISTANCE (steepness of plots: linear regression coefficient = 0.285, $P = 0.089$; basal area at breast height: linear regression coefficient = 0.001, $P = 0.851$; amount of litter: linear regression coefficient = –0.169, $P = 0.115$; road conditions: logistic regression coefficient = –0.021, $P = 0.57$; Fig. 4).

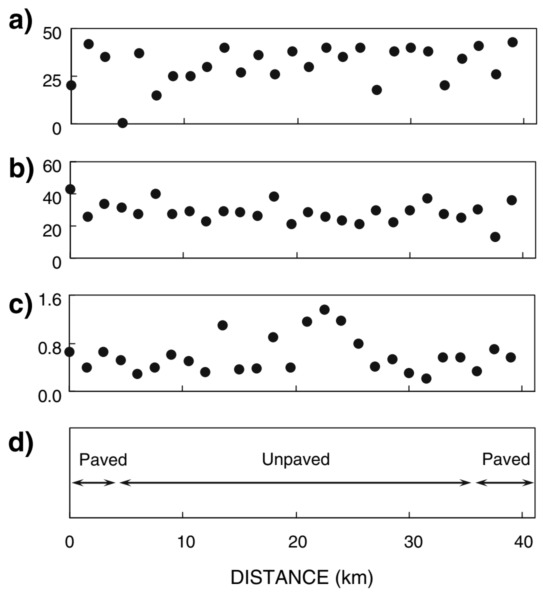

Fig. 4 Environmental conditions along the Amami Central Forest Road (ACF-Road) measured in surveys. DISTANCE is the distance from the release point of mongoose along the ACF-Road. (**a**) Steepness of plots (°), (**b**) amount of leaf litter (g/30 × 30-cm quadrat), (**c**) basal area at breast height (m^2/30 × 2-m transect), (**d**) road condition (paved or unpaved)

Discussions

Our results suggest that the mongoose has had a strong negative effect on seven species of ground-dwelling larger native animals, including mammals (Amami rabbit), birds (Amami woodcock), reptiles (Ryukyu odd-tooth snake and Ryukyu short-legged skink), and amphibians (Amami tip-nosed frog, Otton frog, and Ishikawa's frog), to the extent that they were rarely observed in mongoose-infested areas. All of these are endemic to the Nansei Islands and depend on the forest of Amami Island as the main habitat. Thus, to protect the remaining native animals, it is essential to prevent further expansion of the mongoose's distribution.

It is at the same time noteworthy that not all ground-dwelling animals were vulnerable to mongoose invasion. In contrast to the larger seven species mentioned above, neutral or even positive relationships with the history of mongoose establishment were shown in middle-sized and smaller-sized animals, respectively. These patterns could not be explained by the direct effects of the mongoose. One possible explanation is that smaller species have increased in abundance through top–down cascades, i.e., decreases in native predators such as frogs, snakes, and lizards caused by the mongoose have resulted in increases in the abundance of smaller animals. This process could be explained by size-selective predation and differential diet ranges between the mongoose and native predators. Although the diet range of the mongoose includes all animals described in this study (Gorman 1975; Abe et al. 1999), larger animals are more likely to be vulnerable to mongoose predation because generalist predators should feed selectively on more profitable prey. On the other hand, prey of frogs, snakes, and lizards, is probably restricted to smaller prey because native predators are smaller than the mongoose and their prey size also appears to be limited by their gape size. Therefore, predation pressure on smaller animals is likely to be stronger from native predators than from the mongoose, leading to a trophic cascade caused by mongoose. Predation pressures by mongoose and native predators may be canceled out for medium-sized animals such as small frogs and the camel cricket, causing neutral responses to mongoose by these animals. As other unknown processes might have been associated with these patterns, further investigations including manipulative field experiments are required.

Our results showed that the effect of micro-habitat in daytime of native animals could not explain their distribution patterns. Previous studies showed that prey of the mongoose consist mainly of nocturnal species (Abe et al. 1999; Environmental Agency et al. 2000; Yamada et al. 2000), many of which use refuge in daytime, such as tree cavity or underneath of dead logs. This indicates that the mongoose does search such refuges for prey. Indeed, it was reported that the nest cavity of Amami rabbit was attacked by the mongoose (Yamada personal communication).

Because our study has no replication, the above patterns may have resulted from factors other than the mongoose. However, we have several reasons to believe mongoose causality. Firstly, none of the environmental conditions examined were correlated with the history of mongoose establishment (Fig. 4). Secondly, there are before-invasion records of the Amami rabbit (Sugimura et al. 2000, 2003; Yamada et al. 2000; Sugimura and Yamada 2004) and three species of larger frogs, i.e., the Amami tip-nosed frog, Otton frog, and Ishikawa's frog (Toyama et al. 1989), in areas where the mongoose has now been established for a long period. Thirdly, the patterns found in this study do not seem to be restricted to our census route. Actually, several target species including Amami rabbit (Sugimura and Yamada 2004), Amami woodcock (Ishida et al. 2003), Otton frog and Ishikawa's frog (Iwai and Watari 2006), were less abundant in sites other than ACF-Road where the mongoose has now been established for a long period. Lastly, the distribution of other exotics cannot sufficiently explain the detected patterns. The exotic black rat is distributed widely irrespective of the mongoose establishment (Fig. 2). Also, the distributions of cats and dogs were highly biased to areas near the release point of the mongoose, which were clearly more restricted compared with the areas where native vertebrates were absent (Fig. 2).

Unlike the vegetation degeneration or soil erosion caused by large herbivores, community-wide top–down effects induced by exotic top predators are inconspicuous. Moreover, most of the studies assessing the effects of mongoose thus far have been limited to a particular species or taxon. This study appears to be the first example that shows the influence of mongoose on a wide variety of native animals. We also found differential vulnerability among the native species, including positive indirect effects on small animals. This indicates the importance of considering the food web structure of a recipient ecosystem. Our findings contribute to the prediction and assessment of ecological risks caused not only by mongoose, but also by other invasive top predators.

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Appendix

Appendix A Traits of native animals used in this study

Common name	Scientific name	Body weight (g)	Microhabitat in daytime[b]
Amami rabbit	*Pentalagus furnessi*	2000	Hide
Amami woodcock	*Scolopax mira*	500	Exposed
Ryukyu odd-tooth snake	*Dinodon semicarinatum*	400	Hide
Ryukyu short-legged skink	*Ateuchosaurus pellopleurus*	6	Exposed
Amami tip-nosed frog	*Rana amamiensis*	60	Hide
Otton frog	*Rana subaspera*	250	Hide
Ishikawa's frog	*Rana ishikawae*	100	Hide
Small frogs[a]		5.5	Hide
Camel cricket	*Diestrammena gigas*	3	Hide
Yellow-spotted cricket	*Cardiodactylus guttulus*	0.8	Exposed
Amami forest cockroach	*Episymploce amamiensis*	0.08	Exposed
Satsuma small cockroach	*Margattea satsumana*	0.04	Exposed

[a] Small frogs includes Ryukyu brown frog (*Rana okinavana*), ornate narrow-mouthed toad (*Microhyla ornata*), and Ryukyu kajika frog (*Buergeria japonica*)

[b] ''Hide'' means those animals using refuges in daytime such as tree cavity and underneath of dead logs, so that mongoose needs to search actively to detect them. ''Exposed'' means those animals staying on the ground or trees, or underneath of leaf litter. It seems that mongoose can easily find exposed animals because they flush or come out of litter as mongoose walks around

Appendix B Frequency of occurrence of native animals that were observed using nighttime driving census

Common name	Scientific name	Number of individuals
Mammals		
Amami rabbit	*Pentalagus furnessi*	46
Ryukyu wild boar	*Sus scorofa riukiuanus*	1
Birds		
Amami woodcock	*Scolopax mira*	63
Reptiles (snakes)		
Ryukyu odd-tooth snake	*Dinodon semicarinatum*	12
Habu	*Trimeresurus flavoviridis*	2
Hime habu	*Trimeresurus okinavensis*	1
Amphibians (frogs)		
Amami tip-nosed frog	*Rana amamiensis*	112
Otton frog	*Rana subaspera*	10
Ishikawa's frog	*Rana ishikawae*	6

Numbers represent the total occurrence during the four surveys

Appendix C Frequency of occurrence of arthropods that were captured using adhesive traps in each study period

Class	Order	Family or scientific name	Number of individuals
Insecta	Blattodea	*Episymploce amamiensis*	197
		Margattea satsumana	83
		Symploce japonica	19
		Opisthoplatia orientalis	6
		Periplaneta japanna	2
		Rhabdoblatta guttigera	1
		Unidentified or juvenile[a]	43
	Orthoptera	*Cardiodactylus guttulus*	260
		Diestrammena gigas	184
		Duolandrevus ivani	33
		Traulia ornata amamiensis	1
	Dermaptera	Unidentified	1
	Coleoptera	Scarabaeidae	1
		Lampyridae	1
	Thysanura	Machilidae	2
Chilopoda	Scutigeromorpha	*Thereuopoda clunifera*	1
	Scolopendromorpha	Unidentified[a]	3
Diplopoda	Polydesmida	*Chamberlinius hualienensis*	3

[a] Includes multiple taxa

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