Population Trend, Habitat Change and Conservation of the Unique Wildlife Species on Amami Island, Japan

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Abstract

Amami Island has many terrestrial wildlife species and subspecies that are endemic to the Nansei Archipelago. Many of them live in the forest ecosystems, while young secondary forests have replaced the majority of the original forests due to the past clear-cutting forestry. Of those species, the great scaly thrush *Zoothera dauma major*, Owston white-backed woodpecker *Drendrocopos leucotos owstoni*, long-haired rat *Diplothrix legata* and Amami pygmy woodpecker *Dendrocopos kizuki amamii*, appear to be so dependent on the mature forests (uncut for at least 50 years after selective felling) that their numbers must have decreased at least for the last few decades. On the other hand, the populations of Amami rabbit *Pentalagus furnessi*, purple jay *Garrulus lidthi*, Amami woodcock *Scolopax mira*, Ryukyu robin *Erithacus komadori* and spinous rat *Tokudaia osimensis* have decreased in the central part of the island, where mongoose numbers have skyrocketed in recent years. In the mean time, forestry practices that turned out to be economically unprofitable have resulted in a precipitous decline in production in the early 1990s. Mongoose control has also encountered critical financial problems due to the ignorance of the local community. These situations are rooted in a local economy that has been deeply dependent on government subsidies, which facilitated various development activities.

Key words: endemic species, forestry, invading predators, local economy, mature forests

1. Introduction

Amami Island, located at 28°N, 129°E, belongs to the Nansei Archipelago (the Nansei Islands), a chain extending from the south of Kyushu to the east of Taiwan (Fig. 1). Island populations are the most vulnerable to extinction (Williamson, 1981), and this is also true for the Nansei Archipelago and the Ogasawara Islands. They are smaller than the Japanese Islands and have many endemic species that are included in the red list of the IUCN or the Ministry of the Environment (former Japan Environment Agency). Stattersfield *et al*. (1998) nominated both of these islands as the most urgent among the 76 areas in the world for the conservation of the endemic bird species. WWF International also ranks the Nansei Archipelago as one of the "critical or endangered" terrestrial ecoregions.

The forest ecosystems on Amami Island as well as in Yambaru (the northern part of Okinawa Island) (Fig. 1), in particular, sustain a large number of endemic species of the Nansei Archipelago. Yet, less than 1% of the forests on Amami Island have been protected from such development activities as logging, constructing large entertainment parks, vehicle roads, etc. Extensive clear-cut forestry has been conducted primarily for pulpwood production from the 1950s through early 1990s, so mature forests remain small (Sugimura, 1988; Sugimura, 1995) (Fig. 2). In addition, Java mongooses *Herpestes javanicus* that were released in 1979 for the purpose of controlling a venomous snake, the habu *Trimeresurus flavoviridis*, has been expanding its distribution from the site of release (Fig. 1) (Yamada *et al*., 2000).

Thus, the endemic species in the forest ecosystems have been threatened by habitat changes and introduced predators. Nevertheless, there are few long-term studies that deal with their population trends and impacts of these changes on them (Sugimura, 2002). On the other hand, government subsidies have played a critical role in the local economy and facilitated various kinds of development activities (Sugimura, 1988).

The objectives of the present paper are as follows:

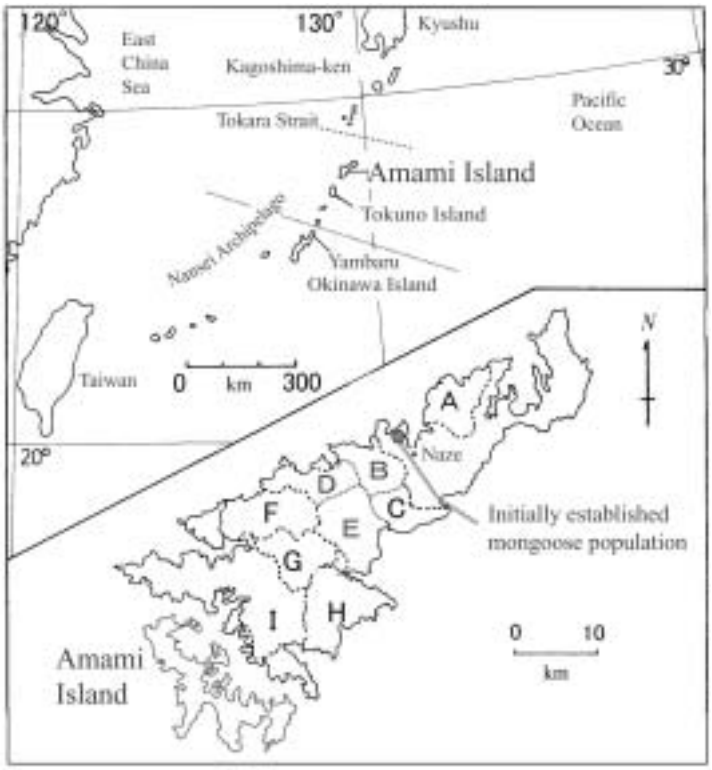

Fig. 1 The location of Amami Island in southwestern Japan. (adapted from Sugimura *et al*., 2000)

Fig. 2 Typical forest habitat. (left: mature forest, right: cutover area)

(1) to get an overview of the characteristics of the terrestrial vertebrate fauna, (2) to examine the population trends of the wildlife species endemic to the Nansei Archipelago, (3) to speculate on some factors that appear to be the major causes of the trend, and (4) to propose effective conservation measures taking the social background into account.

2. Geographical Background

Amami Island is the second largest island in the Nansei Archipelago: 819.5 km^2 including three other smaller islands in the vicinity. All the statistics given in the present paper include these three islands unless specified. It is the largest island in the Amami Insular Group that is located in the southernmost part of Kagoshima-ken (one of the 47 prefectures or administrative districts of Japan). The island is mountainous with a forest cover of 85%, and its highest peak is 694 m. Precipitation is abundant throughout the year (2,871 mm average over 30 years (Kagoshima-ken, 2002)) creating densely distributed tributary systems (Fig. 3). The soil is generally not very suitable for agriculture due to abundant rainfall that often laterizes it (Oshiro, 1984). Besides, typhoons occasionally cause great damage to the soil with strong winds and high salinity (Ishijima & Itokazu, 1980).

The middle and southern parts of the Nansei Archipelago (south of the Tokara Strait) became isolated permanently from Kyushu about 1.5 million years ago - long before the islands north of the Tokara Strait (Fig. 1) were separated from the continent - and have a number of endemic species and subspecies of

Fig. 3 Abundant precipitation throughout the year creating densely distributed tributary systems.

terrestrial animals that are not found elsewhere (Kizaki & Oshiro, 1980; Otsuka & Takahashi, 2000). About ten thousand years ago the Okinawa Insular group was separated from Taiwan and the southern part of the Nansei Archipelago. No land bridge has formed over the Kerama Strait (Fig. 1) since then (Otsuka & Takahashi, 2000). As a result, the fauna and flora of the Okinawa and Amami insular groups are distinctive not only by virtue of endemism but also some primitive types of species whose closest phylogenic relatives are found in Southeast Asia or Tibet, while the biota of the Japanese Islands is closely associated with that of the Asian Continent lying northwest of Japan.

Accordingly, Amami Island has a number of endemic species and subspecies of terrestrial vertebrates. They are listed in Table 1 along with some subspecies of particular concern. Particularly noted is a large number (17 species) of endemic reptiles and amphibians, reflecting a long geological period of isolation from the continent and their poor dispersal ability. The Nansei Archipelago has as large a number of endemic species as the Japan Islands for these groups, indicating a high level of endemism despite of its small geographical area.

Table 1 Species of terrestrial vertebrates on Amami Island that are endemic to the Nansei Archipelago (subspecies of particular concern are also depicted).

Common name	Scientific name	Distribution	RDB category
Mammals			
Amami rabbit	*Pentalagus furnessi*	AO, TS	EN
Long-haired rat	*Diplothrix legata*	AO, TS, OH	EN
Spinous rat	*Tokudaia osimensis*	AG, OH	EN
Watase's shrew	*Crocidura watasei*	AG, OG	NT
Orii's shrew	*Crocidura orii*	AO, TS	EN
Ryukyu bent-winged bat	*Miniopterus fuscus*	NS south of TR	EN
Birds			
Purple jay	*Garrulus lidthi*	AO	VU
Amami woodcock	*Scolopax mira*	AG	EN
Ryukyu robin	*Erithacus komadori*	NS, DG	VU
Great scaly thrush	*Zoothera dauma major*	AO	CR
Owston white-backed woodpecker	*Dendrocopos leucotos owstoni*	AO	EN
Amami pygmy woodpecker	*Dendrocopos kizuki amamii*	AO	VU
Reptiles			
Tree-climbing lizard	*Japrula polygonata*	NS south of TR	VU
Green kanahebi	*Tokydromus smaragdinus*	TR, AG, OG, MG	
Dark-edged hime lizard	*Ateuchosaurus pellopleuru*	NS	
Barbour lizard	*Eumeces barbouri*	AG, OG	VU
Oshima lizard	*Eumeces marginatus*	TR, AG, OG	
Amami Takachiho	*Achalinus werneri*	AG, OG	NT
Riukiu green snake	*Entechinus semicarinatus*	TR, AG, OG	
Akamata	*Dinodon semicarinatus*	AG, OG	
Glass hibah	*Amphiesma pryeri*	NS south of TR	
Hyan	*Calliophis japonicus*	AG, OG	NT
Hime hab	*Trimeresurus okinavensis*	AG, OG	
Habu	*Trimeresurus flavoviridis*	AG, OG	
Amphibians			
Hallowel green frog	*Hyla hallowelli*	AG, OG	
Riukiu red frog	*Rana okinavana*	AG, OG	
Ishikawa frog	*Rana ishikawae*	AG, OG	EN
Amami tip-nosed frog	*Rana amamiensis*	AO, TS	VU
Otton frog	*Babina subaspera*	AG	VU
Amami green frog	*Rhacophorus viridis*	AG, OG	
Anderson's crocodile newt	*Tylototriton andersoni*	AO, TS, OG	VU
Sword-tailed newt	*Cynops ensicauda*	AG, OG	NT

Distribution: DG (Danjo Insular Group); TR (Tokara Insular Group); AG (Annami Island Goup), AO (Amami Island), TS (Tokuno Island); OG (Okinawa Insular Group); OH (Okinawa Island); MG (Miyako Insular Group); NS (Nansei Archipelago)
RDB category (in Japan): CR (Critically Endangered); EN (Endangered); VU (Vulnerable); NT(Near Threatened)
Source: WWF Japan Scientific Committee (1984), Ito *et al.* (2000), Japan Wildlife Research Center (2000).

The mammalian fauna of Amami Island includes six endemic species. There are no species on the East Asian Continent closely related to them except Orii's shrew *Crocidura orii* and the Ryukyu bent-winged bat *Miniopterus fuscus* (Motokawa, 2000). The two species of rats have their closest relatives in Sumatra and Celebes (Tokuda 1969, p. 120). Their appearance and habits are unique because of the many spines (modified hairs) on the body of the spinous rat *Tokudaia osimensis* and because of the large size and preference for arboreal habitats of the long-haired rat *Diplothrix legata* (Fig. 4). The Amami rabbit *Pentalagus furnessi* (Fig. 5) is one of the most remarkable in terms of primitive morphological characteristics (Chapman & Flux, 1990). Yamada *et al*., (2002) estimated that the lineage of *Pentalagus* diversified during the generic radiation of the leporids in the middle of the Miocene based on molecular phylogeny.

Of particular concern among the birds are the purple jay *Garrulus lidthi*, Amami woodcock *Scolopax mira* and great scaly thrush *Zoothera dauma major* (or *amami*) because of their small range of distribution. The purple jay (Fig. 6) used to live on Tokuno Island (personal communication with Mr. Tsuneda), but there is no recent record of its survival (Ishida *et al*., 1990). Because of its conspicuousness, this must mean it is extinct there. The great scaly thrush is generally regarded as a subspecies that is endemic to the Amami and Kakeroma Islands. Ishida *et al*. (1998) thought that it should be identified as a species based on its geographical isolation, distinctive territorial song and morphological characteristics. Monroe and Sibley (1993) also classified it as a species according to a phylogenic analysis. On the other hand, the Ryukyu robin *Erithacus komadori* is noted in particular for its aesthetic value. Even during the feudal period before the Meiji Restoration of 1868, the feudal clan of the current Kagoshima presented it alive to the *shogun*, hereditary generalissimo of the central government in Edo (present Tokyo) because its warble was so beautiful.

Fig. 4 Arboreal long-haired rat, total length of an adult is over 50 cm. (Yoshitaka Takatsuki)

Fig. 5 Amami rabbit, retaining primitive morphological characters. (Yoshitaka Takatsuki)

3. Population Trends of the Unique Wildlife Species

3.1 Mammals

There have been few population surveys except for the Amami rabbit. Monitoring pellet count is normally the only viable approach and it has been used frequently, although various census techniques have been applied to lagomorph populations (Seber, 1982).

The first Amami Island rabbit-pellet count was conducted in 1976 (Anon, 1977). They reported that pellets were numerous on every forest road they visited on the island. During the two periods, 1985-1986 and 1989-1990, pellets were counted along forest roads in regions B to F (Fig.1) (Sugimura, 1988;

Fig. 6 Purple jay endemic to Amami, Kakeroma and Uke Islands.

Sugimura, 1998). These studies indicated that the rabbit most heavily used secondary forests, 10 to 40 years after clear-felling. Yet, in spite of an increase in the area of young forests due to continuous cutting, they indicated a significant decline in the distribution and abundance between the two periods. Later, Sugimura *et al*. (2000) estimated the distribution and abundance of the Amami rabbit, counting their fecal pellets along streams and forest roads. They estimated the distribution area as around 370 km^2 on Amami and 33 km^2 on Tokuno Island. Some populations were completely isolated and thought to be very small. They compared the results of this study with those of previous studies and indicated that the Amami rabbit's total population had declined over the last two decades.

The study in 1976 suggested 233 pellets km^{-1} day^{-1} as the average number on three forest roads visited daily. In the central part of Amami Island the average fecal abundance decreased from 47.2 in 1985-1986 to 13.3 pellets km^{-1} day^{-1} in 1989-90 (Sugimura, 1987; Sugimura, 1993). In the 1993-1995 studies the figures were 15 pellets km^{-1} day^{-1} for the same area and 19 pellets km^{-1} day^{-1} for the whole range. Thus, the population seems to have declined significantly after 1976. As to the change in distribution area, Anon (1977) estimated the range based on a questionnaire, interviews and pellet searches on some forest roads. When the past range was compared with the fecal distribution in the 1993-1994 studies, it appeared to have retreated in the northern part (Fig. 7). A study conducted in 2002 revealed further decrease in the distribution area in regions B and D possibly due to the invading mongoose as described later.

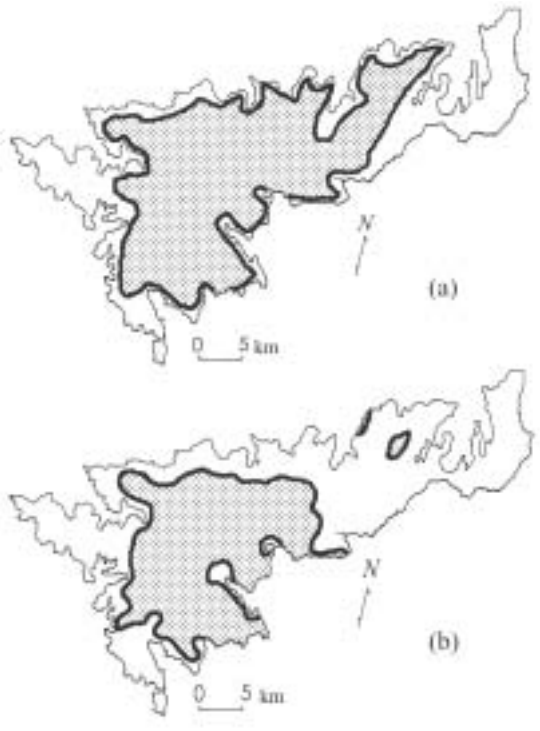

Fig. 7 Change in the estimated distribution range from 1976 (a) to 1993-1994 (b) on Amami Island. (modified from Sugimura *et al*., 2000)

The Amami spinous rat is found on Amami and Tokuno Islands (Motokawa, 2000; Japan Wildlife Research Center, 2000). The forest area of Tokuno Island is much smaller than that of Amami, and the rat is found almost exclusively in forested areas (Sugimura, 1987). Therefore, the populations on Amami Island may be essential for the survival of the species. According to Sugimura (1987), 5.9 rats were trapped alive per 100 trap-nights in the winter of 1985-1986 in various ages of stands in regions B to E (Fig. 1). No rat was caught in the same area in the winter of 1994, while 1.9 rats were caught per 100 trap-nights in the winter of 1995 in regions farther south (Japan Environment Agency, 1995). Yamada (unpublished) has recently identified many black rats *Rattus rattus* in automatic flash photographs taken in the areas where none of the spinous rats was caught in 1985-1986. These findings, along with the frequent observation of black rats by other field researchers (personal communication with Ishida, K. and Takashi, M.), suggest that the black rat might have replaced the spinous rat in regions B to E.

The long-haired rat is primarily arboreal and a cavity nester in relatively large trees (Ikehara *et al*., 1981; Suzuki, 1985). It is found on Amami, Tokuno and Okinawa Islands (Motokawa, 2000; Japan Wildlife Research Center, 2000), and Ikehara *et al*. (1981) suggested that the population size on Okinawa would be much smaller than that on Amami Island. Yet, even on Amami Island this species appears to be much less frequently observed than it was before the Pacific War, since Suzuki (1985) and T. Nakamura (personal communication), a former forester at the Amami National Forest Office, noted that local people used to observe groups of individuals living together in mature forests moving around inside the canopy layer. When the distribution is compared between before and after 1980 according to information collected through a questionnaire and interviews, it was found that the area decreased and fragmented after 1980 (Japan Wildlife Research Center, 1994).

3.2 Birds

In the breeding and wintering seasons of 1985-1986 numbers of 19 species of birds were recorded according to the sample-count method (Bond, 1957), establishing over 50 sampling stations along logging roads in regions B and E (Fig. 1) (Sugimura, 1988). The same species of birds were enumerated by the same method in April 1993, February 2001 and April 2001 in order to compare changes in abundance. Selecting five unique species and comparing their average numbers observed at each sampling station per visit, all of them were found to have decreased in number during the fifteen-year interval (Fig. 8). In particular, the purple jay and Japanese wood pigeon

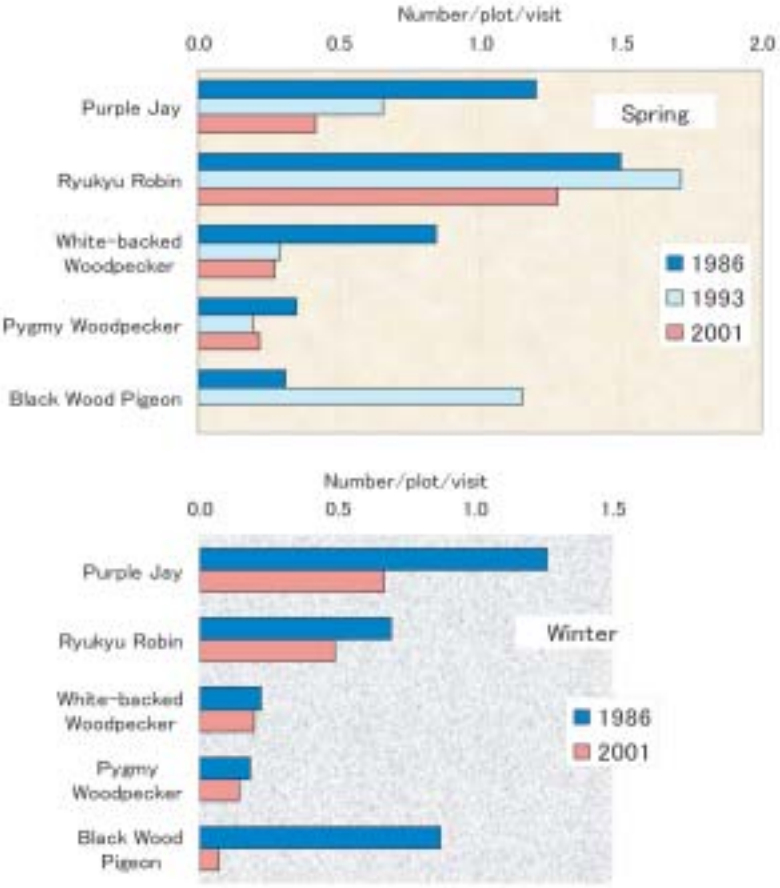

Fig. 8 Comparisons of the average number of birds observed at a sampling station per visit among the 1986, 1993 and 2001 censuses.

Columba janthina were much less abundant in 2001. The Ryukyu robin appeared to have increased in 1993, but declined in 2001. Sugimura (2002) compared the abundance of the jay and the robin between regions B and E. He found that the abundance did not differ significantly between the two regions in 1986 and 1993 for either species. However, both species were less numerous in regions B than E in 2001. In contrast, the numbers of the two woodpecker species, white-backed woodpecker *Dendrocopos leucotos* and pygmy woodpecker *Dendrocopos kizuki*, did not differ much between the two periods or between the two regions (Sugimura, 2002).

Regarding the other species of concern, the Amami Ornithologists Club conducted a survey on the great scaly thrush over its distribution range in 1990 and has continued it annually since 1994. They estimate that the surviving number is quite small, possibly around 100 individuals, and indicate that there has been no obvious increasing or decreasing trend during the past several years. As for the Amami woodcock there has been no effective method of monitoring its population, since it has no territorial song and seldom makes conspicuous sound. Counting those that appear on forest roads at night is the only viable method. Yet they were observed in regions B, C and D in 1985 and 1991, while no birds were counted in the same regions in 1994 (Sugimura, 1987; Kanai & Ishida, 1995).

In addition, comparing other species between 1985-1986 and 2001, only three among 14 species were found to be more abundant, namely the ashy minivet *Pericrocotus divaricatus*, great tit *Parus major* and varied tit *Parus varius* (Sugimura, 2002). Three species, the brown-eared bulbul *Hypsipetes amaurotis*, Japanese white-eye *Zosterops japonicus* and narcissus flycatcher *Ficedula narcissina*, showed no great changes in number. The other eight species revealed a decline, namely the whistling green pigeon *Sphenurus formosae*, Oriental turtle dove *Streptopelia orientalis*, Japanese paradise flycatcher *Terpsiphone atrocaudata*, jungle crow *Corvus macrorhynchos*, Japanese bush warbler *Cettia diphone*, pale thrush *Turdus pallidus*, black-faced bunting *Emberiza spodocephala* and grey-faced buzzard *Butastur indicus*. In summary, 12 of the 21 bird species described in this section decreased in number, seven showed no great changes and only three species showed an increase in number.

4. Habitat Changes and Their Effects on Unique Wildlife Species

4.1 Forests and forestry

Broad-leafed evergreen forests (particularly of evergreen oak *Castanopsis sieboldii* and Iju *Schima*

wallichii) dominate the islands. Perennial grasses *Miscanthus sinensis* and ferns *Dicranopteris pedata* predominate in cutovers (Shimizu *et al.*, 1988), in which forests will eventually recover with natural regeneration from shoots of the dicotyledonous species that formerly prevailed. The afforested area is not large (less than 20% of the entire forest area), which is mostly occupied by Ryukyu pine *Pinus luchuensis* and a relatively small area of Japanese cedar *Cryptomeria japonica*. Plantation forestry has not yet proven to be commercially profitable and most plantations have been abandoned after receiving subsidies from the government.

Before the Second World War, forests were selectively logged and most of the forests in the central mountains suffered little human disturbance. Sugimura (1995) and Sugimura *et al*. (2000) defined both these and uncut forests as mature forests that must have covered the mountains extensively. It is generally thought that all of those threatened taxa had, in the past, been dependent on mature forests of broad-leafed evergreen trees. Forest trees had not been heavily utilized before the national government started the Amami Insular Group Recovery Project in 1954. Since then, a number of logging roads have been built with a large amount of financial aid. Timber production on Amami Island peaked in 1963 and again in 1972, but declined suddenly within a few years after reaching the second peak (Fig. 9). The decrease was particularly marked for saw-lumber relative to pulpwood due to a decrease in the area of mature forests. The total area of mature forest in 2000 was estimated to be about 40% of that in 1970, accounting for about 9.1% of the forest area on the island (Table 2). Extensive young secondary forests, observed all over the island, are the consequence of whole-tree harvesting, which cleared forests completely, without leaving a single tree or snag on the site.

Table 2 Change in the area of mature forests on Amami Island.

Year	1970	1980	1990	2000
Area（thousand ha）	15.66	9.78	7.28	6.33

The areas were estimated from aerial photographs, ground observations and forestry statistics (Sugimura, 2002).

Most of the trees that are ready to be cut at present have low commercial value, as young broad-leaved trees and pines, which are currently overwhelmingly dominant on Amami Island, can be processed only for pulpwood. Forestry on Amami Island yields only a negative 'profit' as a whole when financial aid from the government is taken into account (Sugimura, 1988), as is also suggested in Fig. 9. Thus, logging may be economically feasible only by means of government subsidies, most of which have been granted for construction of logging roads, reflecting large demand for public engineering works as a source of employment for the local society. The subsidies for forestry development amounted to 2,645 million yen (*ca*. $22 million), of which 60% was spent for road construction in the fiscal year 2000 for the whole Amami Insular Group (Kagoshima-ken, 2002). In spite of such a large amount of subsidies the amount of cutting decreased drastically in the early 1990s.

4.2 Effects of forestry

Sugimura *et al*. (2000) attempted to illuminate the relationship between the impact of clear-cutting forestry and the population of the Amami rabbit. They divided the whole distribution range arbitrarily into 39 sub-regions (average 770 ha) using ridge lines, vehicle roads and rivers. Each sub-region borders on a few to several adjacent sub-regions. Then, they analyzed the rabbit abundance in each sub-region statistically and obtained the following equation.

$$\ln P = 1.3\ln N + 0.0019 * (68 - M) * M + 0.057L + 1.0 \quad (R^2 = 0.61,\ p < 0.001)$$

(*P*: the number of pellets observed per km; *M*: percentage of mature forest; *L*: percentage of cutover; *N*: the average number of pellets observed per km in the neighboring sub-regions weighted by the length of the border with each sub-region).

Descriptions of mature forests and cutover are given in the previous section. Young secondary forests covered the largest area on the island, and the percentage of mature forests (*M*) was below 34% for the majority of sub-regions. Therefore, this equation suggests that the rabbit's abundance is positively correlated with *M*. That is, the larger the area of mature forests, the higher was the rabbit's abundance.

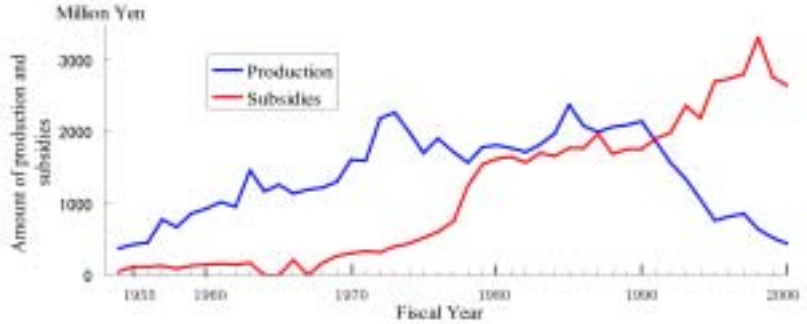

Fig. 9 Amount of output of primary forest products and government subsidies for forestry in the Amami Island Group.

It also suggests that opening up a forest may contribute to an increase in the abundance of the Amami rabbit by providing herbaceous food sources on the ground. Sugimura (1988) also suggested that a mixture of mature and young forests would make up a suitable habitat for the rabbit over the long term. He found more pellets in young secondary forests close to mature forests than in young secondary growth further from mature forests.

As to the spinous rat, Sugimura (1988) suggested that it would be negatively affected by logging for a while until young secondary forests cover the area. The same genus on Okinawa Island was trapped in evergreen forests of *Castanopsis* trees but not in agricultural fields (Mitsui & Ikehara, 1979). In addition, Suzuki (1985) indicated that the acorns of *Castanopsis* trees in winter were a major food source. Therefore, the spinous rat may be negatively affected by the loss of mature forests, since they yield a larger amount of acorns than younger stands. On the other hand, the decline in the area of the mature forests since 1990 has not been as large as before (Table 2). So the recent population decline reported by the Japan Environment Agency (1995) would have been caused by some other factors.

In contrast, it is obvious that extensive clear-cutting forestry has had a great negative impact on the long-haired rat, because their habitat is primarily arboreal and they use relatively large trees with cavities in the trunk as nest sites. Although available information is scarce, their distribution area has decreased and has become more fragmented, as noted before.

As for the birds endemic to the Nansei Archipelago, comparing their abundance among logged areas, young secondary forests and mature stands in the central part of Amami Island, Sugimura (1987) and Sugimura (1988) found that four of these, the Ryukyu robin, white-backed woodpecker, great scaly thrush and Amami pygmy woodpecker, exhibited substantial population declines when mature forests were clear cut. Only the purple jay was found frequently in young forests. Ishida *et al*. (1995) also indicated that the habitat preference of the great scaly thrush was primarily mature forests of broad-leafed trees, where the soil was relatively wet. According to Ishida *et al*. (1998) the Amami woodcock also prefers mature forests to young stands in which pioneer pine trees coexist. Therefore, the majority of the endemic species would be negatively affected by clear-cutting of mature forests.

There are some species of birds that appear to prefer young forests, such as the Japanese wood pigeon, brown-eared bulbul and buntings *Emberiza* spp. (Sugimura, 1987). The same study suggested that the Japanese bush warbler, Japanese white-eye, jungle crow and Oriental turtle dove would not be negatively affected by the loss of mature forests, but 13 out of 20 species would be negatively affected. Among these, the Japanese wood pigeon revealed a precipitous population decline in the winter and spring censuses of 2001, compared with the censuses 15 years before (Sugimura, 2002). It is not clear how forest habitat change is related to population decline.

4.2 Invasive predators

Those who are concerned about the unique wildlife on the island have indicated a need to control feral cats and dogs since the 1970s. Sugimura (1994) reported that 11 out of 15 feces of dogs he found on forest roads contained rabbit hairs. He has found a few pieces of cat feces only once on a forest road, which contained abundant rabbit hairs, in an area where rabbit density was supposed to be one of the highest. Nakano and Murai (1996) reported that they found signs of predation by feral dogs on the spinous rat and the long-haired rat. Mr. Minami (personal communication), a late professional habu hunter, observed a feral cat killing a rabbit that was climbing up a slope. He suggested that the rabbits would be more vulnerable to cats than dogs, since dogs would not be able to climb up the slope. Anyway it is certain that they may threaten the survival of some rabbit populations. Another piece of evidence is that there is an inverse relationship between the population density of the Amami rabbit and the human population in the close vicinity (Sugimura, 2002). The population size of feral cats and dogs is potentially large in areas where the human population is large. The human population has gradually declined since the end of the Pacific War (Sugimura, 1987) to about a half its past level, and it is still decreasing. So the number of cats and dogs they keep may also have decreased, as long as the average family keeps nearly the same number of cats and dogs. Besides, forest road construction decreased in the 1990s to about one third of the level in the 1970s and about a half of that in the 1980s. Feral cats and dogs travel along the roads, which expanded into the interior of the island in the 1970s and extended more densely in the 1980s. Yamada (unpublished) has recently recorded the presence of many cats and dogs in the forest of the interior part of the island by automatic flash photography. Therefore, even though they may still threaten the survival of some local populations of the unique wildlife species, they do not explain the recent population decline of the Amami rabbit and spinous rat that has taken place over a wide range of their distribution.

In contrast, the mongoose has rapidly increased its population size (Yamada *et al*., 1999). It was probably released at Akasaki in Naze around 1979 (Fig. 1). Since then, it has expanded its distribution range from region B towards regions E and F by 10 km in ten years and later over 20 km in 18 years. It preys on the Amami rabbit, spinous rat, purple jay, Ryukyu robin and other endemic species (Abe *et al*., 1991; Abe, 1992; Yamada *et al*., 2000). Because the total mongoose population has increased rapidly and

they prey on rabbits, they have probably contributed to lowering the rabbit's population. Figure 10 indicates that the rabbits decreased from 1985-1986 to 1993-1994 in every region surveyed. Subsequently, their pellet numbers decreased in regions B, C and D, where the mongoose has a higher population density, while they increased in the other regions except region H (Sugimura, 2002). Also, rabbits were less abundant in the vicinity of cities and towns, where feral dogs and cats are more frequently observed (Sugimura *et al*., 2000). These observations imply that predation may be an important factor in the decline of the rabbit on Amami Island.

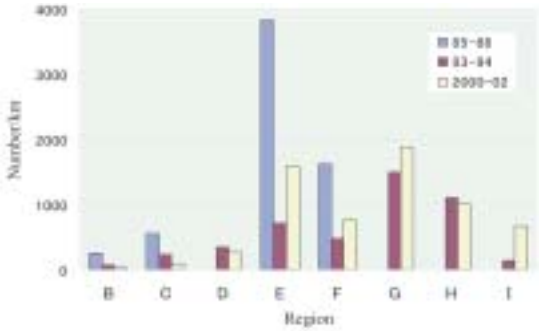

Fig. 10 Change in the number of fecal pellets of the Amami rabbit observed in recent years on Amami Island.

More recently it has been indicated that black rats are observed frequently in the interior of the island, where Sugimura (1987) was not able to trap any of them. Ishida (personal communication) suggested that they might climb up trees and raid bird nests. The rat was introduced to the island long time ago. They have been abundant in sugar cane fields as the major prey for the habu. It is not clear why they suddenly increased their population in the interior of the island. The coincidence with the precipitous decrease in spinous rat populations implies that there may have been competition for food sources between the two rat species.

5. Steps toward Reasonable Conservation Planning

5.1 Local economy

The textile industry has been the most important among the productive industries, as it produces expensive market wares, i.e., pongee fabric with a special texture for making Japanese kimonos. However, it has suffered a serious depression especially since 1985 (Kagoshima-ken, 2002). Besides, this primary industry of Amami Island is small for a rural area in terms of the percentage of people employed in it, which is, roughly speaking, one fifth of that of the other islands in the Amami Insular Group and about a half of that of Kagoshima-ken. Thus, every self-supporting productive industry in the island economy is small, so that it is inevitable that the local society has been largely dependent on financial support from the national and prefecture governments to the Amami Insular Group, of which Amami Island contains 56% of the total population. As a result, the secondary industry, in which construction for public enterprises is most important, has the largest number of people employed.

Based on statistics provided by Kagoshima-ken (2002), the prefectural and national governments contributed in total 144,928 million yen (*ca*. $1,200 million) to the local governments in the 2000 fiscal year. This enormous amount of funds suggests how important government subsidies were not only to sustaining the industries but also to creating jobs for the 73,896 people living on the islands in the year 2000. Estimating from the statistics provided by Kagoshima-ken (2002), public engineering works accounted for more than 50% of the jobs.

5.2 Forest management

As suggested previously, the great scaly thrush, Owston white-backed woodpecker and long-haired rat, must have all suffered substantial population declines because of extensive clear-cutting. They will probably not be able to maintain their populations if no mature forests (primary forests and old secondary forests) are retained. Small populations of the Ryukyu robin may be able to survive in young secondary forests, but population decline will be substantial because of the decrease in the area of mature forest.

Mosaics of young and mature forests are still abundant in the central and the southern parts of Amami Island. Therefore, primary conservation measure in such areas would be to limit forest road construction. This measure would restrict the logging of more mature forests and help prevent the isolation of some local populations.

Forestry has been subsidized by the national and prefectural governments to a large degree, and has provided construction companies with a considerable amount of work. As a result, most of the mature forests have been replaced by young secondary forests and logged areas (Sugimura, 1988). The governments involved have planned to manage those young forests for pulpwood, even though it is of low commercial value. Yet, the economic inefficiency of the forestry industry has helped most of the young forests to recover for these ten to twenty years in the central part of the island. Therefore, it would be wise to pursue a forest management policy of stopping the loss of mature forests and encouraging long- rotation management of less mature forests (Harris, 1984).

One possible procedure would be a shift in the use of government subsidies to aim at a longer rotation-cycle and a shift from construction of logging roads to silvicultural experiments for forest conservation and more efficient use of mature forests. At the same time, the subsidies could provide jobs for local people so as to maintain the current contribution of the forestry industry to society.

5.3 Controlling predators

Information on feral cats and dogs is so limited that their effects cannot be ascertained. Researchers have indicated the importance of their control since the late 1970s, while they recognized the problem of the mongoose to be serious in the 1990s (Sugimura, 2002). The Japan Environment Agency started investigating the ecology and the status of the mongoose in 1994. At present the same agency (promoted to a ministry in 2001) and the local governments are involved in capturing mongooses and attempting to eradicate their populations. However, Yamada (2002) doubts the effectiveness of these projects. First, they have been trapping mongooses mainly near residential and agricultural areas far from the core distribution areas of the indigenous species. Second, the trapping period does not coincide with the breeding season, so the population may recover soon. Therefore, it is essential to investigate the effects of the mongoose on the indigenous species, endemic species in particular. This should make it clear which species is to be protected as the first priority and in which area.

A budget can be allocated from the large amount of government subsidies. Even a small portion of the budget that has been used for public engineering projects would be sufficient to provide economic incentives for trappers to catch a larger number of mongooses.

Concluding Remarks

Although most of the endemic species that the present paper deals with may not yet be on the brink of extinction, it is most likely that their populations have been declining (Table 3). Therefore, certain measures do need to be taken if they are to be conserved. Sugimura *et al*. (2000) suggested that three measures would be effective for the Amami rabbit, and this would also be true for the other species of concern. They are (1) to restrict extensive logging of mature forests to maintain a widespread mosaic of cutover and mature forests; (2) to control predators (feral cats and dogs and introduced mongooses); and (3) to cease forest road construction that may encourage further expansion of predators in forests.

One of the major obstacles facing policy decision-makers with regard to bringing these measures into practice will be that the value of these species is intangible and difficult to quantify when they have to give it priority over a human activity, such as road construction, whose benefits are visible and readily quantifiable. Yet, construction of a forest road itself does not yield sufficient economic benefits, so reducing the number of roads to be built could save a substantial amount of subsidies. Then, the amount of subsidies saved could be invested in predator controls and monitoring the populations of some unique species. Once it has been shown that a particular human disturbance (logging or the invading mongoose in the present study) can be mitigated, the benefits of species preservation do not have to be stated precisely in contrast with those of development activities. It will become apparent that the cost of this kind of preservation is small relative to the amount of subsidies to be saved.

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Table 3 Population trends of the unique wildlife species of concern in the present paper.

Common name	Population trend	Most probable or likely causes
Mammals		
Amami rabbit	Decline in area and density	Logging, predators*
Long-haired rat	Decline in area and density	Logging
Spinous rat	Decline in area and density	Logging, predators
Birds		
Purple jay	Decline in density	Predators
Amami woodcock	Decline in area and density	Logging, predators
Ryukyu robin	Decline in density	Logging, predators
Great scaly thrush	Decline in area and density	Logging
Owston white-backed woodpecker	Decline in density	Logging
Amami pygmy woodpecker	Decline in density	Logging

*Predators are mainly mongooses and feral cats and dogs

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