Rich Biota in the Forests of Yanbaru, Northern Montane Part of Okinawa Island, Japan, and Imminent Extinction Crisis of the Endangered Species

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Abstract - Yanbaru, the northern montane portion of Okinawa Island, has historically been dominated by evergreen bloadleaf forests with remarkably rich biota, but many parts of the forest are now being destroyed as a result of government policy. Although there are many endemic animals and plants in the remaining natural forests, many of them are now in imminent risk of extinction. The status of populations of vertebrate animals listed in the Red List is described. Species diversity in Yanbaru forests is possibly highest among all Japanese forests, and this may be a dominant cause of the evolution and maintenance of many endemic species. However, the diversity has been diminished by forest cutting and removal of forest undergrowth by government subsidies. Suspension of clear-cutting and undergrowth removal, and change of proposed helipad sites from natural forest areas are necessary to preserve the unique biota of this area.

I. Introduction

Yanbaru, the northern montane portion of Okinawa Island (Okinawa Hontô), the largest island of the Ryukyu Archipelago of Japan, is an important area from the viewpoint of nature conservation, because it supports a number of specialized endemic animals and plants. The Ryukyu Archipelago (hereafter RA) is situated in southwestern sea between Kyushu and Taiwan (Formosa). It exists in the Oriental Region in a different biogeographic division from mainland Japan, which is in the Palearctic Region. Climax vegetation of RA consists of evergreen bloadleaf forests, usually dominated by the evergreen oak, *Castanopsis sieboldii*. RA is one of a small number of wet subtropic areas which includes Taiwan, northern Thailand and the Florida Peninsula (the climate of most other subtropic areas is dry). However, due to destruction of much of the natural forests during World War II and serious exploitation since the return of Okinawa to Japan, large natural forests are now remain in only three areas, Amani-Toku Area (including two islands, Amani-Oshima and Tokunosima), Yanbaru, and Iriomote Island. As shown in Figure 1, many parts of natural forest of Yanbaru were cut (denoted as secondary forests), except the area occupied by the US Marine Corps Northern Training Area. Although true virgin forest is restricted to a few small sites because a large part of Yanbaru forest was subjected to thinning or clear-cutting, forest sections that were thinned or cut 40-50 years ago have recovered the basic features of the climax community. Following the definition of the Nature Conservation Society of Japan [1], we refer to the parts of the Yanbaru forest dominated by *Castanopsis sieboldii* trees older than 30 years as natural forests. Here, I report on the rich biota of Yanbaru, the imminent extinction crisis of endangered endemic animals, and high species diversity which has supported the endemic animals.

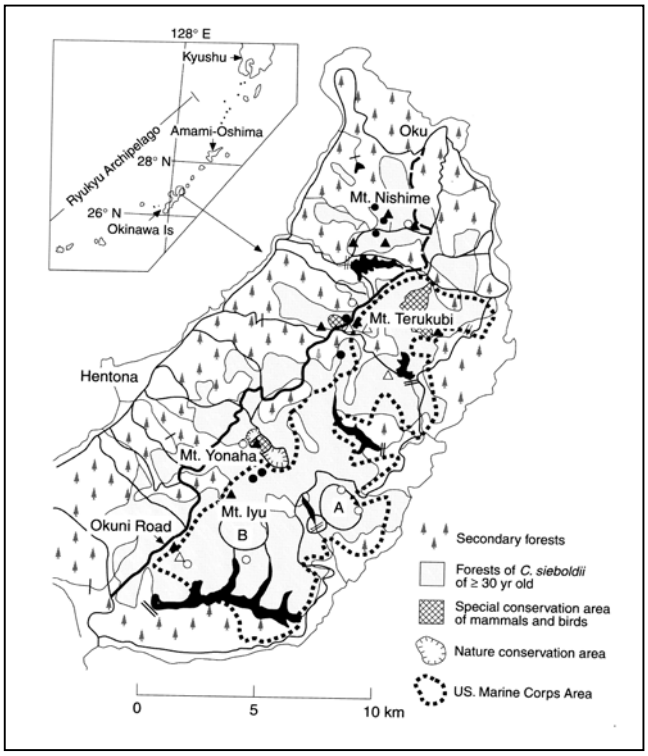

Fig. 1. Map of Yanbaru, showing natural forests, US Marine Corps Northern Training Area and areas proposed for establishment of Marine Corps helipads (A and B).

II. Number of Vertebrate Species and Their Extinction Crisis in Yanbaru

Among 108 species of mammals living in Japan, 10 species (six introduced species, *Rattus rattus*, *R. norvegicus*, *Mus musculatus*, *Herpestes javanicus*, feral cats and dogs are excluded) are found in Yanbaru [2]. This number indicates a remarkably rich mammalian fauna in this area, because the size of Yanbaru is only 0.08 % of the total area of Japan. In addition, 2 species, the Yanbaru whiskered bat, *Myotis yanbarensis*, and the Ryukyu tube-nosed bat, *Murina ryukyuana*, and 1 subspecies, the Okinawa spiny rat, *Tokudaia osimensis mueninki*, are endemic to Yanbaru only, and 7 species are endemic to RA.

Twenty-two bird species are known to reproduce in forests of Yanbaru (*Passer montanus* and 2 introduced species and species which reproduce in seashore or sites around lakes or ponds are excluded; for names, see [2]). Of these, 2 species, the Okinawa rail, *Gallirallus okinawae*, and the Noguchi's woodpecker (Pryer's woodpecker), *Sapheopipo noguchii*, are endemic to Yanbaru only, and two species, the Japanese lesser sparrow hawk, *Accipiter gularis*, and the Amami woodcock, *Scolopax mira*, are endemic to RA at the species level. Of the remainder, 17 are endemic to RA at the subspecies level. Only the Japanese wood pigion, *Columba janthina janthina*, is seen in both RA and the main islands of Japan.

Table I shows numbers of critically endangered, endangered, and vulnerable species of vertebrates included in the revised Red Lists of the Japanese Environmental Agency (now Ministry of Environment) [3,4]. This indicates that Yanbaru has a large proportion of these species despite its small area.

Table II shows the names of critically endangered and endangered vertebrate species living in Yanbaru. Note that two new species of bats, *Myotis yanbarensis* and *Murina ryukyuana*, were found quite recently (in 1997).

Although we lack good quantitative data on the current population size and rate of recent population decline of these species, the numbers of individuals of these animals, found in recent years by many field biologists working in Yanbaru, indicate that several populations are near extinction. That is, only 3 individuals, including 2 specimens used for the description, of *M. yanbarensis*, and about 10 individuals of *M. ryukyuana* have been previously found. For the Okinawa spiny rat, only 2 dead individuals were observed and only 1 living individuals was photographed (using an ultraviolet-activated camera) from 1995-1999, although spinous hairs of this species were found recently in the feces of feral cats. A living individual and a dead individual of the Ryukyu long-haired rat, *Diplothrix legata*, were found in 1999; these are only specimens that have been found during 5 years (1995-1999). The mean numbers of these 4 species are believed to be fewer than 1000. Based on counts of nest holes and identification of adults using playback of recorded territorial songs, the number of Noguchi's woodpecker was estimated to be between 400 and 500 [5]. The number of the Okinawa rail is considered to be far less than 10,000 [2].

TABLE I
Number of Critically Endangered, Endangered and Vulnerable species, living in all of Japan and Yanbaru, described in the new Red List of the Environmental Agency of Japan [3,4].

Category		Mammals	Birds	Reptiles	Amphibians
CE	Japan	12	17	2	1
	Yanbaru	2	1	0	0
E	Japan	20	25	5	4
	Yanbaru	4	2	0	1
V	Japan	16	48	11	9
	Yanbaru	0	2	4	4

CE: Critically Endangered
E: Endangered
V: Vulnerable

TABLE II
Names and Endemism of Vertebrate Species Living in Forests of Yanbaru, Listed as Critically Endangered and Endangered Species in the Red List of Environmental Agency

Category	Organisms	Endemism*
Critically Endangered		
Mammals		
	Yanbaru whiskered bat, *Myotis yanbarensis*	Yanb.
	Okinawa spiny rat, *Tokudaia osimensis mueninki*	Yanb.subsp
Birds		
	Noguchi's woodpecker, *Sapheopipo noguchii*	Yanb.
Endangered		
Mammals		
	Okinawa least horseshore bat, *Rhinolophus pimilis*	O & M
	Ryukyu bent-winged bat, *Miniopterus fuscus*	RA
	Ryukyu tube-nosed bat, *Murina ryukyuana*	Yanb.
	Ryukyu long-haired rat, *Diplothrix legata*	A, T & Yanb.
Birds		
	Okinawa rail, *Gallirallus okinawae*	Yanb.
	Amami woodcock, *Scolopax mira*	A, T & O
Amphibians		
	Ishikawa's frog, *Rana ishikawae*	A & Yamb.

*Endemic to localities described. Yanb. : Yanbaru, O: Okinawa Island (including Yanbaru), A: Amami Island, T. Tokunoshima Island, M: Miyako Island, RA: Many islands in the Ryukyu Archipelago. Yanb. subsp of the Okinawa spiny rat means this subspecies is endemic to Yanbaru (Species is endemic to A, T and Yanbaru).

III. Biodiversity in Yanbaru Forests

Species diversity is one of the most important aspects of the biodiversity, and high species diversity may be an important factor of evolution and maintenance of many endemic animals and plants in small islands.

Many indices have been proposed to measure species diversity, including species richness and heterogeneity of numbers of individuals among species in a community. We used three indices, log (1/*D*), 1−*D*, and *H'* ;

$$D = \sum \frac{n_i(n_i - 1)}{N(N-1)}$$

and

$$H' = -\sum (n_i / N) \cdot \log_2 (n_i / N).$$

N is the total number of individuals and n_i is the number of individuals of *i*th species. 1−*D* and log(1/*D*) were recommended for comparison of species diversity of different communities by Lande [6] and Itô and Sato [7], respectively. Large values of these indices indicate high species diversity (but for 1−*D*, the maximum value is 1). Although *H'* has most frequently been used for this purpose, this index has a weakness, namely that is strongly affected by the sample size [6, 7, 8]. However we still used this index because this is sensitive to changes in rare species in the community, in contrast to 1−*D* and log (1/*D*), which are sensitive to changes in the most abundant species [9].

Table III shows the number of species, total number of individuals, and species diversity calculated for trees, insects living in the forest floor, ground ants and oribatid mites living in soil.

As shown here, the diversity of tree species in the natural forests (> 50 years old) of Yanbaru is much higher than that of the deciduous broadleaf forests of Hokkaido, and higher than the evergreen broadleaf forests of Kyushu (see [10] for detailed explanation). Table III also demonstrates that tree species diversity of the secondary forests (< 20 years old) of Yanbaru is lower than that of natural forests. Tree species diversity of the forests of Yanbaru is possibly the highest among Japanese forests (near that of tropical rain forest [10]). Three diversity indices show similar trends in relation to localities, ages and conditions of forests, not only for trees but also for insects and mites, but values of log (1/*D*) may be best indicator.

The natural forests of Yanbaru show high species diversity of insects ([11], for values of "no u. g.", see later), similar to the natural forests on Iriomote Island. The value for secondary forests on Iriomote is lower than for natural forests. The species diversity of ants, using data collected from 30 min counts of nests, also show a far higher diversity in Yanbaru than in Hokkaido [12].

TABLE III

Number of species (*S*), total number of individuals (*N*), and species diversity indices [log(1/*D*), 1−*D* and *H'*] of some groups of plants and animals in Yanbaru and some other places. Mean ±s.d. was shown for data of three or more samples. DBH: Diameter at breast height. Regarding insects, ants and oribatid mites, "natural" means natural evergreen forests while "no u. g." means forests from which the undergrowth was completely cut and removed.

Group and area	*S*	*N*	log(1/*D*)	1−*D*	*H'*
Trees (DBH > 4.5 cm). Surveyed area: 4 a in Yanbaru and Kyushu, 5 a in Hokkaido					
Yanbaru natural forests(>50 yr old)	29.4±2.5	149±26	1.10±0.04	0.92±0.01	3.66
Yanbaru secondary forests (<20 yr old)	23.7±10.4	191±92	0.79±0.19	0.83±0.07	3.31
Hokkaido	5	80.5	0.48	0.34	0.96
Kyushu	12.8±2.4	181±4	0.68±0.30	0.79±0.10	2.85
Insects (sweep net survey, Lepidoptera, Hymenoptera and Diptera are excluded)					
Yanbaru, natural	75.7±3.1	282±47	16.5±5.7	0.94±0.02	5.03
Yanbaru, no u. g.	66.7±4.5	553±200	7.3±2.9	0.85±0.06	4.12
Iriomote, natural	58	202	15.8	0.94	4.94
Iriomote, secondary	53	256	6.6	0.85	4.00
Ants (Counting of nests during 30 minutes)					
Yanbaru, natural	14	43	10.0	0.90	3.41
Hokkaido	7	183	1.50	0.33	1.08
Iriomote	16	46	7.29	0.86	3.35
Oribatid mites (Tullgren extraction of 3 soil samples of 10 X10 X 5 cm)					
Yanbaru, natural	38±8	161±31	15.0±5.3	0.93±0.03	4.38
Yanbaru, no u. g.	33±10	293±176	9.30±0.73	0.89±0.01	3.84

IV. Destruction of the Yanbaru Forest

Since 1972, when Okinawa was returned to Japan, the natural forests of Yanbaru have been seriously damaged in two ways: (1) by large scale clear-cutting, and (2) by undergrowth removal [2].

The extent of Yanbaru forests cut during the 13 years from 1979 to 1991 was 2,443 ha. Nearly half of all natural forests outside of the US Marine Corps Area was clear-cut. Complete cutting and removal of undergrowth (i.e. tree seedlings, shrubs and herbs smaller than 2 - 3 m) was also carried out under a government subsidy through the "Natural Forest Improvement Project". The undergrowth was removed from 3,069 ha of the forest over a 21-year period from 1972 to 1992. Although this area includes some secondary forests, we estimated that the undergrowth was removed from about a half of the natural forests [2, 10].

Large scale clear-cutting of the forests completely deprives the endemic biota of the natural habitat. Even the removal of undergrowth affects populations of ground animals such as the Okinawa spiny rat, the Ryukyu long-haired rat, the Okinawa rail, and small animals living in the forest floor.

Table III shows that the species diversity of insects and mites in 'no undergrowth forests' is always lower than that of intact natural forests. Although the total number of individuals (*N*) in forests without undergrowth was apparently larger than that in the intact forests, this was due to an outbreak of some insect species, which are not normal inhabitants of the natural forests, but are aliens feeding on rotten logs or herbs invaded into the 'gaps' of forests without undergrowth.

The values of species diversity indices, however, are not the only important consideration; the characteristics of the species found in the natural forests are important as well. Table IV shows that all of the oribatid mite species affected by the removal of undergrowth (except for *Pergalumna intermedia*) are known only from RA or Yanbaru (including 2 newly-described species), while all those unaffected by undergrowth removal (except for *Dimidiogalumna azumai*) are cosmopolitan or widely-distributed species. This fact suggests that many endemic small animals have been seriously damaged by the removal of undergrowth, and some of them might have become extinct already.

Another problem associated with clear-cutting and undergrowth removal is soil erosion. Erosion of soil into the coastal ecosystem has killed corals and inhibits their recovery (corals around Okinawa have historically been one of 18 most species-rich corals in the world, but are now undergoing serious destruction [14]). The estuaries of about 80 percent of rivers in Yanbaru area have been blocked by the soil and sand [2]. Although water can pass into the sea through infiltration, diadromous fish and crustaceans, including several endemic species, became unable to swim up to rivers or to return to the sea.

During the 20th century, US Marine Corps Area provided large natural areas for the conservation of biodiversity and endemic species (see Fig. 1). However a new problem arose in 1999. According to the Special Action Committee on Okinawa, by the governments of Japan and USA, the northern portion of the Marine Corps Area will be returned to Japan. Following a request from the US government, the Defense Facilities Administration Agency of Japan is planning to construct seven new helipads in southern part of the Marine Corps Area, in place of their location in secondary forests to be returned to Japan. Two sites proposed are shown in Figure 1; both lie in Yanbaru's best natural forest areas. If this proposal is carried-out, construction activities and noise from helicopters may interrupt breeding activities of endemic animals.

For the preservation of nature and avoidance of extinction of endemic animals and plants in Yanbaru, suspension of clear-cutting and undergrowth removal and relocation of proposed helipads sites are necessary. The Ecological Society of Japan repeatedly has requested these actions to the national and prefectural governments, and some foreign societies, such as the American Bird Conservancy assisted this action. But the destruction is still continuing. We sincerely wish for the attention and assistance of scientists in IUFRO with this problem.

TABLE IV
Distribution of oribatid mite species affected by undergrowth removal and those relatively un-affected by it. (n. s.) shows species newly described during our survey [13].

Distribution	Species
A. Species of which number of individuals were remarkably decreased by undergrowth removal	
Endemic to Ryukyus	*Perscheloribates clavatus torquatus*
	Galmna glanalata
	Trichotocepheus amamiensis
Hokkaido & Okinawa	*Pergalumna intermedia*
Yanbaru only	*Yambaramerus itoi* (n. s.)
	Allogalumna rotundiceps (n. s.)
B. Species of which number of individuals were not decreased (or increased) by undergrowth removal	
Cosmopolitic species	*Oppiella nova*
	Rostrozetes ovulum
Mainland & Okinawa	*Eremovelba japonica*
	Hammerella pectinata
	Arcoppia vioerea
	Yoshiobodes nakatamarii
	Zetorchestes aokii
	Dolicheremaeus baloghi
Yanbaru only	*Dimidiogalumna azumai* (n. s.)

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