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INTRODUCED ANIMALS IN THE DIETS OF THE OGASAWARA BUZZARD, AN ENDEMIC INSULAR RAPTOR IN THE PACIFIC OCEAN

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KEY WORDS: *Common Buzzard*; *Buteo buteo toyoshimai*; *insular subspecies*; *diet*; *introduced animals*; *Bonin Islands*; *Ogasawara Islands*.

The Ogasawara buzzard (*Buteo buteo toyoshimai*) is an insular subspecies of the Common Buzzard (*B. buteo*), endemic to the Ogasawara (Bonin) Islands, in the Pacific Ocean (Momiyama 1927, Ornithological Society of Japan 2002). This hawk may be distinguished from a closely-related subspecies, the Japanese Common Buzzard (*B. buteo japonicus*), by its less brown or lighter plumage, a longer bill, and shorter wings and tarsi (Momiyama 1927). The distribution of the Ogasawara buzzard is very restricted, and this hawk is classified as endangered in Japan (Ministry of Environment 2002). Recently, Suzuki and Kato (2000) reported on the abundance of the Ogasawara buzzard on Chichijima, and estimated that less than 85 pairs of this subspecies inhabited the Ogasawara Islands.

Insular raptors are likely to be sensitive to environmen-

tal changes as are many other insular predators (e.g., Cade and Jones 1993). Therefore, ecological information including dietary data are needed to develop conservation strategies for the population. However, little information on the food habits of the Ogasawara buzzard are currently available.

Many researchers have investigated the diet of the continental subspecies of the Common Buzzard, especially in Europe. As a result, the Common Buzzard is well known to capture and consume various kinds of invertebrates and small- to medium-sized vertebrates. Common prey include reptiles, birds, and rodents depending on environmental conditions (e.g., Cramp and Simmons 1980, del Hoyo et al. 1994, Jedrzejewski et al. 1994, Swann and Etheridge 1995, Reif et al. 2001, Sergio et al. 2002).

The native fauna of the Ogasawara (Bonin) Islands was originally characterized by low species richness because of the island's volcanic origin, and its small size and relatively great distance from the other islands and mainland of Japan (Tsuyama and Asami 1970). Human colonization of the islands began in the 1830s. After that

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time, it was likely that a number of exotic animals were introduced intentionally or unintentionally. Some of these introduced species have become very common. Conversely, many native animals have become extinct. For example, about a third of breeding land birds have gone extinct (Ornithological Society of Japan 2002). As a result, the present fauna of the Ogasawara Islands is composed of a mix of introduced exotic species and some surviving native species.

Several authors have incidentally reported that the Ogasawara buzzard consumed rodents, some birds, green anoles (*Anolis carolinensis*), and marine toads (*Bufo marinus*; Takano et al. 1970, Wild Bird Society of Japan 1975, Nakane et al. 1980, Ueda and deForest 1988, Suzuki and Chiba 1995, Kawakami 2000). Villagers also reported that this buzzard preyed upon domestic fowls (Suzuki 1982) and migrant egrets (*Egretta* sp. and *Bulbulcus ibis*; Y. Iida pers. comm.). Despite these anecdotal reports, the food habits of the Ogasawara buzzard have not received any quantitative study.

Here, we provide quantitative data on the diet of the Ogasawara buzzard, derived from a broader ecological study of this endemic insular raptor. We also describe some of the basic ecology of this species, information that is necessary to provide for its conservation.

METHODS

Study Area. The Ogasawara (Bonin) Islands are composed of three island groups and situated in the Pacific Ocean, ca. 1000 km south of the mainland of Japan (Fig. 1). It has a volcanic origin and subtropical climates, with an annual mean temperature and rainfall of 23.0°C and 1333 mm, respectively (means from 1986–99 at Chichijima Observatory).

Chichijima (ca. 27°N, 142°E), where we studied the diets of the Ogasawara buzzard, is the largest island of the Ogasawara Islands and 24 km² in area with a high elevation of 326 m. Chichijima was extensively deforested from the late 1880s to the mid 1900s (Katahira 1981). Today, Chichijima is generally covered with relatively low vegetation. About 73% of Chichijima is regenerated native forests and scrubs, and the rest includes coastal forests, exotic low shrubs (*Leucaena leucocephala*), grasses (*Stachytarpheta jamaicensis*), and residential areas; canopy trees in all areas consist of native and introduced species that do not exceed 15 m in height (Shimizu and Tabata 1991).

Land Animals on Chichijima. In addition to the extant native migratory and introduced land vertebrates in Chichijima (Table 1) and accidental visitors of birds, some breeding seabirds are also found on the islands. Nonbreeding visitors are infrequent and breeding seabirds occur in a relatively restricted season of the year depending on the species (e.g., Momiyama 1930, Chiba and Funatsu 1991, Ornithological Society of Japan 2002, Kato pers. observ.).

The native land invertebrates include about 236 species of insects and 63 species of land snails, although many of these have exhibited declines in numbers or already have gone extinct (Kurozumi 1988, Kato 1991).

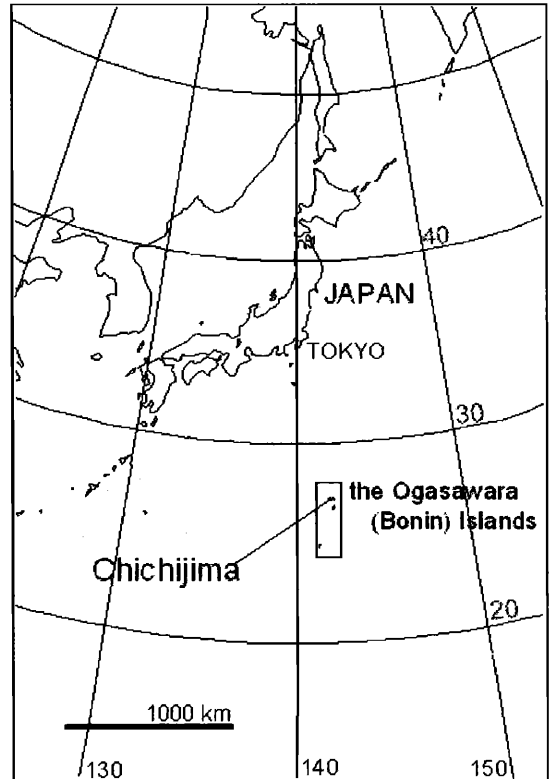


Figure 1. The location of the study area, Ogasawara (Bonin) Islands.

Introduced animals (Table 1; see Tomiyama 1998) are very common now in the islands as well as introduced invertebrates, such as European honeybees (*Apis mellifera*) and African giant snails (*Achatina fulica*). Norway rats (*Rattus norvegicus*) have also been recorded as introduced rodents on the Ogasawara Islands, but recently have not been found in Chichijima.

Data Collection. Data were collected by two methods: (1) observation of hunting or carrying behavior by buzzards from fixed points and (2) observation at nest sites. We conducted general behavioral observations, prey-carrying and hunting behavior for 491 hr in January–June in 2000, 543 hr throughout 2001, and 668 hr in 2002. We also included opportunistic observations in 1998 and 1999. The buzzards were observed with binoculars (8×) and/or a telescope (60×). We pooled all data, because sample size in each year was small. We observed four nests from cliffs during 148.9 hr in May–June in 2000 and one nest for a total of 28.8 hr in May–June in 2001. We watched those nests from hides, which were more than 300 m away. Prey items brought to the nests were identified with a telescope (60×). We took care not to disturb the nesting activity; we generally stopped the observation when a parent on the nest noticed us, or a parent outside the nest displayed an alarm for more than 5 min. Data

Table 1. Present fauna of resident land vertebrates on Chichijima, the Ogasawara (Bonin) Islands.

SPECIES	STATUS ¹
Mammals	
Ogasawara fruit bat (<i>Pteropus peslaphon</i>)	Native
Feral goat (<i>Capra hircus</i>)	Introduced
Feral cat (<i>Felis catus</i>)	Introduced
Black rat (<i>Rattus rattus</i> ²)	Introduced
House mouse (<i>Mus musculus</i>)	Introduced
Birds	
Brown-cheeked Bulbul (<i>Hypsipetes amaurotis</i>)	Native
Bull-headed Shrike (<i>Lanius bucephalus</i>)	Recent immigrant
Bush Warbler (<i>Cettia diphone</i>)	Native
Japanese White-eye (<i>Zosterops japonicus</i>)	Introduced
Rock Thrush (<i>Monticola solitarius</i>)	Native
White's Ground Thrush (<i>Zoothera dauma</i>)	Recent immigrant
Japanese Wood Pigeon (<i>Columba janthina</i>)	Native
Common Buzzard (<i>Buteo buteo</i>)	Native
Reptiles	
Ogasawara snake-eyed skink (<i>Cryptoblepharus boutonii</i>)	Native
Green anole (<i>Anolis carolinensis</i>)	Introduced
House gecko (<i>Hemidactylus frenatus</i>)	Introduced
Morning gecko (<i>Lepidodactylus lugubris</i>)	Introduced
Brahminy blind snake (<i>Typholops braminus</i>)	?
Amphibians	
Marine toad (<i>Bufo marinus</i>)	Introduced

¹ Categorizations are referred from Tsuyama and Asami (1970), and the Ogasawara Natural Environment Study Group (1992).

² Another introduced rat, *R. norvegicus*, formerly resident, has not been found recently.

from nest observations were also combined because of small sample sizes for each nest.

The two methods were not employed on the same day in the same territory, which should have prevented the double counts of the same prey items. For both methods, we were usually able to identify prey animals, because all prey observed were likely species on the limited list of terrestrial vertebrate fauna present in the Ogasawara Islands (Table 1). As black rats (*R. rattus*) and Norway rats are similar in size and shape, it was possible that we mistook one species for the other. However, several sampling surveys have been unable to document Norway rats on Chichijima (e.g., Yabe and Matsumoto 1982, K. Watanabe pers. comm., pers. observ.). Therefore, we assumed that the black rat were the only large rodent prey taken by buzzards and that Norway rats was inconsequential in the diet of this hawk.

In order to evaluate the relative importance of prey species as in the diet on a biomass basis, we weighed dominant prey species using specimens collected by us in Chichijima in 2001. Twenty-three black rats were caught with live traps in August–October, along with 29 green anoles, and 32 marine toads caught by hand in April–May and on 16 September, respectively. As marine toads were caught around a flume where many toads congregated for mating in the night, they were considered all adults. Adult biomass was appropriate for this prey

species because all but one partial food item identified as a marine toad was large and determined to be an adult.

RESULTS

We recorded 156 prey items using the two methods of observations. Among them, we omitted from the analyses 46 prey items that we could not identify.

The Ogasawara buzzard hunted or carried 49 prey items, and 40 of them were identified (Table 2). Black rats ($N = 23$, 57.5%) and green anoles ($N = 9$, 22.5%) predominated in this sample. Marine toads ($N = 2$, 5.0%) and petrels (*Bulweria bulwerii* or *Oceanodroma* sp.; $N = 2$, 5.0%) were next most frequent. A house mouse (*Mus musculus*) and a White's Ground Thrush (*Zoothera dauma*) were also observed ($N = 1$, 2.5%, respectively). One small- or medium-sized bird (2.5%) and one lizard (2.5%) were also recorded as prey, though we could not identify these to the species level.

We recorded 35 (87.5%) of the 40 identified prey items during January–June when the Ogasawara buzzard engages in breeding activities. Six (17.1%; all were black rats) of the 35 prey items were used for flight display by territorial males. Two birds (one thrush and one petrel,

Table 2. Diets of the Ogasawara buzzards observed in Chichijima (1998–2002). Prey items identified at the class level were shown.^a

PREY	NO. OBSERVED		TOTAL	PERCENT	
	HUNTED OR CARRIED	OBSERVED AT NEST			
Mammals					
Black rat (<i>Rattus rattus</i>)	23	32	55	50.0%	
House mouse (<i>Mus musculus</i>)	1	0	1	0.9%	
Birds					
White's Ground Thrush (<i>Zoothera dauma</i>)	1	1	2	1.8%	
Petrel ^b	2	0	2	1.8%	
Small- to medium-sized birds ^c	1	3	4	3.6%	
Reptiles					
Green anole (<i>Anolis carolinensis</i>)	9	27	36	32.7%	
Unknown	1	0	1	0.9%	
Amphibians					
Marine toad (<i>Bufo marinus</i>)	2	7	9	8.2%	
	Total	40	70	110	100.0%

^a Forty-six animals (9 observed hunting and 37 prey deliveries) were excluded from the table because their identity was uncertain.

^b *Bulweria bulwerii* or *Oceanodroma* sp.

^c Small- to medium-sized birds include *Zosterops japonicus*, *Cettia diphone*, *Hypsipetes amaurotis*, *Lanius bucephalus*, *Monticola solitarius*, and *Zoothera dauma*.

5.0%) were fed to fledglings. Though we could not follow the fate of the remaining prey, five (14.3%) of the 35 were likely brought to the nests based on the flight direction of the breeding Ogasawara buzzard. Other prey seemed to be also used for breeding activities (fed to mates and/or offspring) rather than for self consumption.

We recorded 107 prey items during the nest site observations. Sixteen of the prey items were already on the nests when we began the observations. We observed that 101 (94.4%) of the 107 prey items were consumed by either nestlings or the female. Six other items were carried off from the nests by the female parent after the nestling stopped feeding.

We identified 70 (65.4%) of the 107 prey items observed at nest sites (Table 2). Among them, black rats ($N = 32$, 45.7%) and green anoles ($N = 27$, 30.6%) were dominant, followed by marine toads ($N = 7$, 10.0%). The remaining prey items were small- to medium-sized birds.

We combined the data collected by the two different methods, because the prey composition between the two methods was not significantly different ($\chi^2 = 4.13$, $df = 3$, $P = 0.24$). Based on the pooled sample, we identified 110 prey items. There were three predominant species in the diet; black rats ($N = 55$, 50.0%), green anoles ($N = 36$, 32.7%), and marine toads ($N = 9$, 8.2%; Table 2). In addition, we also collected eight pellets in fields incidentally during the study. All of these contained only the remnants of black rats.

To evaluate the relative importance of each prey species as foods, we took body mass into consideration. Many black rats ($\bar{x} = 114.5 \pm 44.2$ g [SD], range = 50–180 g, $N = 23$) and marine toads ($\bar{x} = 91.6 \pm 36.8$ g, range = 35–205, $N = 32$) were more than 100 g, but all green anoles ($\bar{x} = 6.0 \pm 1.6$ g, range = 3.0–9.5, $N = 29$) were less than 10 g. Total biomass consumed during observation was 6298 g for black rats, 216 g for green anoles, and 824 g for marine toads.

DISCUSSION

During this study, we documented the current food habits of the Ogasawara buzzard, an insular endemic subspecies. The number of species taken was very small (Table 2) compared with other populations of the Common Buzzard (e.g., Cramp and Simmons 1980). The main reason for this difference was undoubtedly the low diversity fauna inhabiting the Ogasawara Islands (Table 1). The Ogasawara buzzard primarily caught black rats, green anoles, and marine toads, all of which were introduced animals in the Ogasawara Islands (Tomiya 1998). These three species accounted for ca. 90% of prey items in terms of frequency (Table 2). Black rats are known to be common on many islands of the Ogasawara archipelago. However, green anoles and marine toads are only present and common on two major islands (Chichijima and Hahajima) of the Ogasawara chain. Based on the predominance of these three prey species in the diet of

Table 3. Possible native prey available for the Ogasawara buzzard in the Ogasawara (Bonin) Islands before colonization by human beings and exotic animals.^a

SPECIES	STATUS
Vertebrates	
Mammals	
Ogasawara fruit bat (<i>Pteropus peslaphon</i>)	Endangered
Birds	
Brown-cheeked Bulbul (<i>Hypsipetes amaurotis</i>)	
Bush Warbler (<i>Cettia diphone</i>)	
Bonin White-eye (<i>Apalopteron familiare</i>)	Extinct in Chichijima
Rock Thrush (<i>Monticola solitarius</i>)	
Bonin Islands Thrush (<i>Chichlopasser terrestris</i>)	Extinct
Oriental Greenfinch (<i>Carduelis sinica</i>)	Extinct in Chichijima
Bonin Islands Grosbeak (<i>Chaunoproetus ferreorostris</i>)	Extinct
Jungle Crow (<i>Corvus macrorhynchos</i>)	Extinct
Bonin Wood Pigeon (<i>Columba versicolor</i>)	Extinct
Japanese Wood Pigeon (<i>Columba janthina</i>)	Endangered
Rufous Night Heron (<i>Nycticorax caledonicus</i>)	Extinct
Small- to medium-sized sea birds (e.g., <i>Bulweria</i> , <i>Oceanodroma</i>)	
Occasional migrant visitors (e.g., Ardeidae, Charadriidae, Scolopacidae, and passerines)	
Reptiles	
Ogasawara snake-eyed skink (<i>Cryptoblepharus boutonii</i>)	
Green turtle (<i>Chelonia mydas</i>)	
Invertebrates	
Large insects (e.g., Cicadidae, Buprostidae)	
Land crabs (<i>Geograpsus</i> , <i>Sesarma</i>) and hermit crabs (e.g., <i>Coenobita</i>)	
Large land snails (e.g., <i>Mandarina</i>) extinct or endangered depending on species)	Extinct or Endangered

^a Main sources are Tsuyama and Asami (1970) and Ogasawara Natural Environment Study Group (1992).

the buzzard, the density of these three species appears to be very high on Chichijima Island.

We observed the Ogasawara buzzard to prey upon only few birds (Table 2). The birds appeared to be auxiliary food for buzzard on Chichijima Island during this study. But other researchers have reported some birds as prey of the Ogasawara buzzard. Ueda and deForest (1998) found that the Japanese White-eye (*Zosterops japonicus*) was prey for the buzzard in Chichijima and Kawakami (2000) recorded the White's Ground Thrush, Pacific Golden Plover (*Pluvialis dominica*), and Providence Petrel (*Pterodroma hypoleuca*) in the diet on Hahajima. Furthermore, the Ogasawara buzzard was reported by villagers to hunt migrant egrets (Y. Iida pers. comm.).

The Common Buzzard is known to prey frequently (e.g., Cramp and Simmons 1980) and selectively (Jedrzejewski et al. 1994) on medium-sized birds. The Ogasawara buzzard also hunted White's Ground Thrushes. We suggest that medium-sized birds, especially fledglings and large nestlings because of their relatively large body mass,

could be important prey at times for the Ogasawara buzzard. For example, the mean mass of six adult White's Ground Thrushes was 128 g (Y. Kato, unpubl. data).

We also observed the Ogasawara buzzard preying upon seabirds (e.g., petrels; Table 2), which are generally large compared with passerines. The Ogasawara Islands are known as breeding grounds of seabirds (e.g., Bulwers Petrel [*Bulweria bulwerii*], Wedge-tailed Shearwater [*Puffinus pacificus*], Brown Noddy [*Anous stolidus*], and Brown Booby [*Sula leucogaster*]; Ornithological Society of Japan 2002). We observed that three pairs of the Ogasawara buzzard had breeding territories that included seabird breeding colonies on the islets near Chichijima (Y. Kato, unpubl. data). These three territories were not included in our nest-site studies. As breeding Ogasawara buzzards seem to hunt only within their territories, it was not surprising our list of the prey species was limited to land fauna. Thus, our data may have underestimated buzzard predation on seabirds by excluding territories without seabird colonies.

The number of marine toads (\bar{x} = 91.6 g) taken was less than that of green anoles recorded (Table 2). However, the biomass of marine toads was more than 10 times that of green anoles (\bar{x} = 6.0 g). Thus, we suggest that marine toads may be the more important prey for Ogasawara buzzards. Of course, green anoles might also be an important food if frequent feeding provides the buzzards with stable nutrition.

During the study period, the Ogasawara buzzard largely fed on introduced vertebrates. This dietary pattern is similar as reported in the Hawaiian Hawk (*B. solitarius*) in the Hawaiian Islands (Griffin et al. 1998). These results indicated that the endemic buzzards surviving on selected islands, with drastically modified environments, in the Pacific Ocean now feed on exotic animals introduced by human beings.

Then, what animals did the Ogasawara buzzard feed on before the arrival of introduced animals? Based on the knowledge of the current food habits of the Ogasawara buzzard and of the continental Common Buzzard (e.g., Cramp and Simons 1980), we can speculate about the historical diet of this species. We suggest that the former diet of this buzzard consisted of several medium-sized birds, a couple reptiles, some large invertebrates, and perhaps, the Ogasawara fruit bat (*Pteropus peslaphon*; Table 3).

The Common Buzzard is known to switch from one species of primary prey to another depending on their abundance (Truszkowski 1976, Reif et al. 2001, Selas 2001). In the Ogasawara Islands, about a third of native land bird species have expired since the human colonization (Ornithological Society of Japan 2002), and the abundance of native animals have generally decreased and many of them are threatened with extinction (Tsuyama and Asami 1970). On the contrary, the number of species and the density of introduced animals increased. The predominance of introduced animals in the present diets of the Ogasawara buzzard has probably been caused by the shift in prey availability.

ANIMALES INTRODUCIDOS EN LA DIETA DE *BUTEO BUTEO TOYOSHIMAI*, UN AVE RAPAZ ENDÉMICA A LAS ISLAS DEL OCÉANO PACÍFICO

RESUMEN.—*Buteo buteo toyoshimai* es una subespecie insular endémica distribuida exclusivamente en las islas Ogasawara (Bonin), en el Océano Pacífico subtropical. Esta subespecie se considera amenazada en Japón. La ecología de esta rapaz, incluyendo sus hábitos alimenticios, ha sido poco investigada. En este estudio examinamos cuantitativamente su dieta mediante observaciones directas realizadas entre 1998–2002 en Chichijima, la isla de mayor área (ca. 24 km²) entre las islas Ogasawara. Las presas fueron registradas mientras las aves estaban cazando, mientras aves adultas las cargaban o cuando eran llevadas a los nidos. De los 110 ítems identificados, 55 (50.0%) correspondieron a *Rattus rattus*, 36 (32.7%) a *Anolis carolinensis* y 9 (8.2%) a *Bufo marinus*. Con base en la contribución estimada en términos de biomasa, *R. rattus* fue predominante, seguida por *B. marinus*.

[Traducción del equipo editorial]

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THE DIET OF EURASIAN GRIFFONS (*GYPUS FULVUS*) IN CRETE

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Between a quarter and half of the global range of the Eurasian Griffon (*Gyps fulvus*) population occurs within

Europe (Arroyo 1994). The species is distributed mainly in countries bordering the Mediterranean basin and feeds primarily on livestock carrion (Cramp and Simmons 1980, Donazar 1993). In Crete, the griffon's feeding ecology may be more closely related to pastoralism than anywhere else in Europe. Paleontological findings indicate that all autochthonous-mammal species (apart

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