

Predation of an Introduced Weasel upon the Lizard *Eumeces okadae* on Miyake-jima, Izu Islands

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Abstract Predation on the lizard (*Eumeces okadae*) by a weasel (*Mustela itatsi*) introduced onto Miyake-jima, the Izu Islands, was examined for size selectivity. In 1984, shortly after introduction of the weasel, its food items consisted mainly of *E. okadae* (40-88 % in occurrence frequency) during the period from March to October. By estimating the original body size of prey lizards from the weasel's fecal samples, it was revealed that *E. okadae* of all size classes was susceptible to predation. This predator characteristic is in sharp contrast to that of the native avian predator, *Trudus celanops*, preying primarily upon juvenile lizards.

Key words : weasel, mammalian predation, *Eumeces okadae*, island population.

Introduction

The weasel *Mustela* spp. is frequently used as an agent for the biological control of rats (Miyagi *et al.*, 1975; Shiraishi, 1982). However, its introduction onto islands often results in a catastrophic decrease of the native vertebrates such as birds and reptiles. On the Izu Islands, the weasel *M. itatsi* has been introduced onto Hachijo-jima, Miyake-jima, Aoga-shima and To-shima (Hirano, 1968; Higuchi and Koike, 1977; Higuchi, 1981; Nishikata, 1986). Hirano (1968) and Hasegawa (1986) reported that the lizard *Eumeces okadae* decreased after the introduction of the weasel onto Hachijo-jima and Miyake-jima, respectively. Hasegawa (1990a) demonstrated that, before introduction of the weasel, *E. okadae* on Miyake-jima exhibited a unique life history and demographic characteristics; i.e., low natality, delayed maturity and high survival rate of adult lizards. Thus one plausible explanation for the decrease of *E. okadae* is that predation by the weasel destroyed the balance between survival and natality. However, we still know little about the qualitative and quantitative aspects of weasel predation upon prey lizards.

In this paper, we address three questions concerning weasel predation. First, does the weasel prefer to consume a specific size of prey or is it capable of consuming prey all size classes? Second, when does the weasel hunt lizards? Because *E. okadae* is a strictly diurnal lizard, the weasel

has an option of hunting it when it is active on the ground or of excavating sleeping lizards nocturnally. Finally, what amount of lizards does the weasel consume? We present direct and indirect evidence for the characterization of predation pressure on the lizards of the weasel.

Materials and Methods

A field study was conducted on Miyake-jima (34°05' N latitude, 139°30' E longitude, 5,514 ha) during 1977-1985. In each year, sighting records of the weasel were gathered while MH (M. Hasegawa) conducted the population study of *Eumeces okadae*. The survey was conducted primarily during the day. A nocturnal survey, attempted occasionally by driving a car slowly at an approximate speed of 30 km/h, was unsuccessful. When weasels were sighted, we recorded the time, behavior, approximate body size (in order to distinguish sexes), and prey at the mouth if feeding. No special attempt was made to determine abundance of the weasel; we simply compiled the sighting records, and calculated its abundance as the number of the weasels seen per day. This crude index was sufficient to monitor the long-term change in abundance. During 1977-1985, a total of 248 days were spent for surveying the island.

The sighting records of the weasel increased after 1983. We occasionally found fecal pellets in 1983 but did not collect them. In 1984, fecal pellets were collected monthly from January to October.

Table 1. Sighting records of the weasels (No. seen/day) on Miyake-jima from 1977 to 1985.

	Year								
	1977	1978	1979	1980	1981	1982	1983	1984	1985
# weasels seen	0	0	0	0	0	0	5	11	2
# days surveyed	6	6	22	35	21	31	61	63	3
frequency	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.17	0.67

A total of 54 samples were obtained (4-23 per month). These samples were brought back to the laboratory, and the contents were examined. The pellets were immersed in 25% ethanol, broken into pieces, and sorted tentatively into nine prey categories (centipede, insect, insect larva, fish, reptile, bird, mammal, plant matter and others). These prey remains were picked up separately, air-dried, and deposited for later identification (Nishikata, 1986).

Body size of *E. okadae* consumed by the weasels was estimated from these fecal samples. Skeletal characters indicating body size of prey lizards were lost. Instead, the claws of most digits were well preserved, and in many cases, it was not difficult for us to count the numbers of individual lizards involved in the respective feces. Thus claws seemed to be a suitable material for estimating the original body size of the prey. The third claws of foreleg of preserved specimens of *E. okadae* were measured, and the regression equation for claw length vs. snout-vent length (SVL) was determined.

The quantity of *E. okadae* consumed by the weasel during a given time period was estimated indirectly. A recent advance in the doubly-labeled water technique enabled us to predict the daily food requirement, given the predator body mass (Nagy, 1987). Nagy presented the following simple formula for predicting the daily food requirement,

$$\text{Feeding rate (dry g/d)} = 0.235X^{0.822}$$

for eutherian mammals, where X=live mass of predator. Body mass data for the weasel were cited from the literature on the Hachijo-jima population (Higuchi, 1981).

Results

Table 1 presents the sighting frequencies of the weasels compiled over the nine-years (1977-1985). Higuchi and Koike (1977) reported that 20 male

weasels were firstly released in November and December 1975, and weasels were witnessed 38 times the following year (1976). However, during 1977-1982, no weasels were sighted at all. This suggested that the weasels released in 1975 did not establish a population on Miyake-jima. The first sighting recorded by us was on 9 April 1983 at Tomoji, the northernmost corner of the island. Thereafter, the sighting records increased rapidly from 0.09 in 1983 to 0.66 in 1985. The weasels increased after 1983, probably due to a second illegal release in 1982 (Asanuma, pers. commun.).

All of these sightings were recorded during the daytime between 06:21 and 12:40. Although we did not witness hunting behavior on Miyake-jima, MH observed it on To-shima on 18 April 1981. At 08:24 a male weasel captured a large adult male *E. okadae* and consumed it within one minute. Nakamura (1984) made a similar observation on Hachijo-jima in late May 1967. Between 08:30 and 09:30, a small weasel (probably female) captured four *E. okadae* inhabiting a rock wall. These observation suggested that the weasels foraged diurnally for lizards active on the surface.

Figure 1 shows the occurrence frequency of *E. okadae* in fecal pellets. *E. okadae* was the major

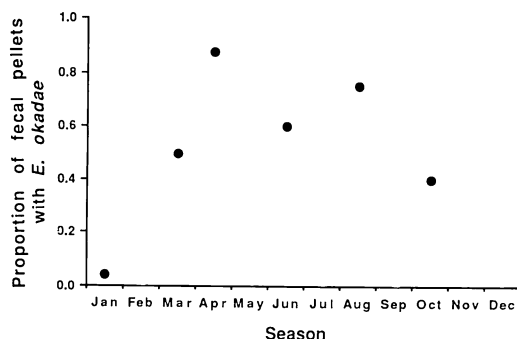


Fig. 1. Occurrence frequency of *Eumeces okadae* in the fecal pellets of the weasel *Mustela itatsi* on Miyake-jima, Izu Islands.

Table 2. Food requirement scaling in *Mustela itatsi* preying upon *Eumeces okadae*.

Sex	Body mass (g)			Feeding rate**		Predation rate (# eaten/d)		
	mean	SD	n	(dry g/d)	(wet g/d)	Yearling (1.5 g)	2-yr-old (5.5 g)	Adult (10.3 g)
Male	417.0	89.4	24	33.48	90.49	60.33	16.45	8.79
Female	170.3	21.5	3	16.04	43.34	28.90	7.88	4.21

prey (40–88% occurrence frequency) during April through October. A total of 25 sets of digits or claws were obtained from 54 fecal samples, representing 25 individual lizards. SVLs of these prey lizards were estimated by reference to the SVL-claw length relationship shown in Fig. 2, and the regression equation presented below,

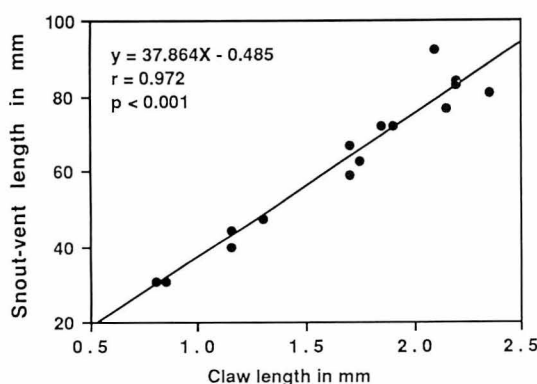
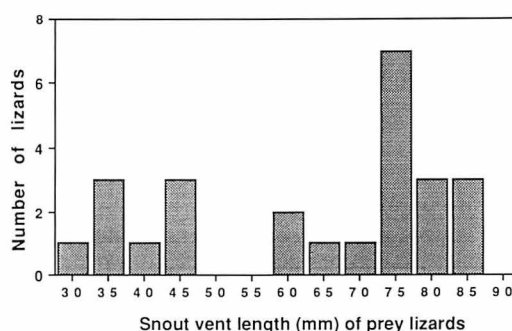
$$\text{SVL} = 37.9 \text{Claw length} - 0.5 \quad (r = 0.972, P < 0.001)$$

The estimated body size ranged from 32 to 88 mm SVL. Comparison of body sizes between the fecal samples and the lizards active in the field (Hasegawa, 1990b) indicated that the weasel was capable of consuming *E. okadae* of all size classes (Fig. 3).

Table 2 summarizes the estimated amount of food required by the weasels to meet field metabolic rates. The mean body mass of the male weasels captured alive was 417.0 ± 89.4 SD with a range of 210–565 g ($n = 24$), and that of females was 170.3 ± 21.5 with a range of 156–195 g ($n = 3$). The estimated consumption rates were 90.5 g/day for males, and 43.3 g/day for females, respectively. Assuming that the weasels satisfied these food requirements by consuming adult *E. okadae* (mean body mass = 10.3 g) exclusively, as indicated in Fig. 1, predation rates were calculated to be 9 adult lizards/day/male weasel, and 4 adult lizards/day/female weasel. A male weasel captured on Miyake-jima on 8 October 1983 weighed 780 g was considerably larger than those on Hachijo-jima. This suggested that the prey consumption rates were somewhat underestimated in comparison with actual predation rates on Miyake-jima.

Discussion

Biological control of rats was the primary reason for the introduction of the weasel onto the islands (Shiraishi, 1982); as was the case for the Izu Islands (Hirano, 1968; Higuchi, 1981; Nishikata, 1986), where necessity for such control was high in the absence of effective native predators or because of low predator density. Aoga-shima and Miyake-jima are free from snakes, representing the former case, and To-shima has a low abundance of snakes, thus representing the latter situation (Hasegawa and Moriguchi, 1989). Hachijo-jima is exceptional, because the viper *Agkistrodon blomhoffii* was formerly very abundant (Goris, 1967). However, it was questionable that *A. blomhoffii* was sufficiently effective to maintain the abundance of rats at a level insignificant

**Fig. 2.** Relationship between snout-vent length and claw length of *Eumeces okadae*.**Fig. 3.** Body size (snout-vent length) distributions of *Eumeces okadae* consumed by *Mustela itatsi* on Miyake-jima in 1984.

for agricultural damage. In any event, the islands suffering from a "rat problem" were suggested to be predator-free (Miyagi *et al.*, 1975), and the densities of other insular vertebrates such as birds and lizards are also very high (Moyer *et al.*, 1985; Hasegawa, 1990b).

The results of this study clearly demonstrated that the weasels newly introduced onto Miyake-jima consumed *E. okadae* voraciously. Lizards of all size classes are susceptible to predation. Due to the high metabolic demand of the weasels, potential prey consumption rates are quite high. The time of hunting seems to be diurnal. These predator characteristics are in sharp contrast to those of the native avian predator of *E. okadae* on Miyake-jima (Hasegawa, 1990a). The thrush *Trudus celanops* was considered to be a size-limited predator capable of consuming only juvenile lizards smaller than 48 mm SVL, though this predator was very abundant on Miyake-jima (Higuchi, 1973).

The introduction and establishment of this voracious mammalian predator alter the mortality schedule of *E. okadae*, destroy the balance between its survival and natality, and finally lead to abolition of population recovery. Hasegawa (1990b) reported that the average summer density of *E. okadae* on Miyake-jima was ca. 4000 (2500 adults and 1500 yearlings)/ha during 1978-1981. Although this density estimate is rather high for the lizards, the weasel can potentially exterminate them. On Hachijo-jima, reduction of *E. okadae* became conspicuous four years after introduction of the weasel (Hirano, 1968). In 1980, nearly 20 years after the introduction, *E. okadae* became extremely rare on Hachijo-jima (MH., personal observation). The decrease of *E. okadae* seemed more rapid on Miyake-jima than on Hachijo-jima. The decrease was apparent even in the summer of 1985 (Hasegawa, 1986), only three years after the probable time of introduction, and by the summer of 1987, *E. okadae* became extremely rare on Miyake-jima.

The weasel is an euryphagous predator whose diet varies considerably according to the relative abundance of potential prey (Furuya *et al.*, 1979; Nishikata and Shiga, 1982; Shiraishi, 1982). Nishikata and Shiga (1982) and Nishikata (1986) argued that weasels can sustain themselves on the islands by changing their major diet from vertebrates to

insects after large-bodied prey are exhausted. In fact, the fecal pellets collected in September 1987 contained no *E. okadae* (unpublished data). By this time, the major prey of the weasel would have shifted from lizards to arthropods such as centipedes in accordance with the rapid decrease of *E. okadae*. Therefore, as long as the weasel persists on Miyake-jima, abundance of *E. okadae* will be depressed to an extremely low level in comparison with the situation before introduction of the weasel.

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伊豆諸島三宅島に移入されたホンDOIタチの オカダトカゲに対する捕食圧

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伊豆諸島の三宅島に人為的に導入されたホンDOIタチのオカダトカゲに対する捕食圧をイタチの糞分析によって調べた。イタチ導入直後の1984年には3月から10月にかけて採集された糞の40~88%にオカダトカゲが含まれていた。糞中に形をとどめていた爪の長さからトカゲの頭胴長を推定した結果、孵化直後の幼体から成体まで全ての大きさのトカゲが捕食されていることが明らかとなった。このような捕食圧は島にもともと生息し、主に幼体を捕食するアカコッコの捕食圧とは質的に異なるものである。