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Food habits of three carnivore species (*Viverricula indica, Herpestes urva,* and *Melogale moschata*) in Fushan Forest, northern Taiwan

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(With 5 figures in the text)

The food habits and degrees of dietary overlap of lesser oriental civet (*Viverricula indica*), crab-eating mongoose (*Herpestes urva*), and ferret badger (*Melogale moschata*) inhabiting the Fushan Forest, northern Taiwan, were studied using faecal analysis between February 1993 and June 1994. Laboratory analysis of 154 civet faeces, and 174 mongoose faeces showed that both species fed on a wide variety of food items, including mammals, birds, reptiles, amphibians, fish, crustaceans, insects, oligochaetes, gastropods, chilopods, arachnids, and plants. Insects, oligochaetes, plants, and mammals were the four most important food items in the civets' diet, whereas crustaceans, insects, amphibians, and reptiles were the four most important food items consumed by mongooses. Amphibians were the only vertebrates, together with invertebrates and plants, found in the 64 ferret badger faeces we analysed, and oligochaetes, insects, and amphibians were the most important food items consumed by ferret badgers. The diversity of diet was highest in the mongoose, followed by the civet, and was lowest in the ferret badger.

The degree of dietary overlap was greatest between the civet and the ferret badger, followed by that of the civet and mongoose. The mongoose and ferret badger had the lowest degree of dietary overlap. However, the degree of dietary overlap varied in different seasons. Invertebrates were the most important food source for the carnivores in Fushan Forest.

Introduction

The study of diet can help us understand the role of a species in the energy flow and nutrient cycle of an ecosystem. It also sets a foundation for the understanding of foraging behaviour, population dynamics, habitat use, and social organization of a species (Mills, 1992). The study of diet in carnivores is particularly important, because they are often at the end of a food chain, and may play an important role in affecting the distribution and abundance of other species. However, diet studies, particularly of the small to medium Asian species of the families Viverridae and Mustelidae, have been rare (Rabinowitz, 1991).

Two viverrids (*Viverricula indica* and *Paguma larvata*), one herpestid (*Herpestes urva*) and four mustelids (*Melogale moschata, Mustela sibirica, Martes flavigula, Lutra lutra*) are known to occur in Taiwan (Chen & Yu, 1984). Except for the many studies on the diet of *L. lutra* in Europe, there has been relatively little study on the diet of these species. Chien, Sheng & Wang (1976) examined the stomach contents of *M. moschata*, and reported that earthworms were a very important food item for this species. Wang, Sheng & Lu (1976) studied the diet of *V. indica* in northern China, and found that the civets ate a lot of rodents and plants. Chen (1989) conducted a preliminary analysis of the food habit of *H. urva* based on 50 randomly collected faeces from all over the island of Taiwan, and Ma

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(1990) collected and analysed 401 scats of *M. sibrica* from the high mountains of Taiwan. Rabinowitz (1991) studied the diet of several civet species, including *P. larvata*, in Thailand. Most of these studies only recorded the overall frequency of occurrence of various food items in the scats or stomachs of a single species. Other published material that could provide information on the diet of these small carnivores is often limited to qualitative description (Lekagul & McNeely, 1977; Ayyadurai *et al.*, 1987; Nowak, 1991). Rarely can one find enough information to compare the diet of these species and seasonal variation, especially where they are sympatric (Rabinowitz, 1991).

In 1992 and 1993, we conducted a survey in Fushan Forest, northern Taiwan, and found that there were at least five sympatric carnivore species. Three of them, *Viverricula indica*, *Herpestes urva*, and *Melogale moschata* were quite abundant, whereas *Mustela sibirica* and *Paguma larvata* were uncommon. However, the capture rate of rodent species, which is often considered as an important food source for carnivores, was extremely low (Lee, 1994). This situation provided us with a very good opportunity to study and compare the diets of these sympatric viverrids and mustelids, and then compare the results with those of the same species inhabiting other places where habitat and food availability might be very different.

Study site

Fushan Forest, an area of 1097.9 hectares lying at the border of Taipei and Ilan Counties, northern Taiwan (24° 46′ N, 121° 34′ E), is protected and managed by the Fushan Research Station of the Taiwan Forestry Research Institute. The elevation of Fushan Forest is between 520 and 1230 m, with most of the area ranging from 600 to 800 m. The forest, which contains the headwaters of two stream systems, Ha-pen and Chou-kan, is divided from north to south into three management zones of about the same size. The northern zone is designated a headwater reserve. The southern zone is designated as Ha-pen Nature Reserve. These two protected areas are little disturbed, and can be visited only by scientists with a permit to conduct research. The central zone is managed as a botanical garden which receives 300 visitors a day almost year round, except in March. There is an artificial pond, inhabited by many species of frogs and freshwater fish, in the botanical garden.

Weather records indicate a warm and humid climate, with a mean annual temperature of 18.4 °C, an annual rainfall of 2900 mm, and a relative humidity of 88% (Chang *et al.*, 1986). The vegetation is mainly subtropical moist hardwood forest with Ebenaceae, Fagaceae, Juglandaceae, Lauraceae, and Theacea being the dominant families of trees.

Materials and methods

The diets of *V. indica*, *H. urva*, and *M. moschata* were studied by analysis of faeces collected along routine transects of trails and stream beds each month between February 1993 and June 1994. The total length of the transects was about 5.5 km. Faeces of different carnivore species can be differentiated based on their size, shape, colour, smell, and the hairs swallowed and left in the faeces when grooming.

Each faecal sample was oven-dried until its weight changed little, and weighed. During analysis, each sample was stirred in warm water, washed through a sieve (0.2 mm), spread evenly in a petri-dish, and the contents were examined under a zoom stereomicroscope. The food items identified in the faeces included both animal and plant matter. The animal matter was divided further into vertebrates and invertebrates (see Table I, Fig. 2). Food items were further differentiated into different orders, families, genera, or even species. However, since not all food items could be identified to the same taxonomic level, we used 11 animal classes and one plant class as the basic food items for comparing the dietary difference among different carnivores.

Two indices were used to quantify the food items in the faeces. Frequency of occurrence of each food item was recorded by examining the percentage of faeces that contained a certain food item. Relative importance of each

TABLE I

Frequency of occurrence (FO) and relative importance (RI) of different food items in the diets of ***Viverricula indica, Herpestes urva,*** *and* ***Melogale moschata***

	Viverricula indica		*Herpestes urva*		*Melogale moschata*	
Food types	FO	RI	FO	RI	FO	RI
Animal						
Vertebrate		**24**		**36.7**		**7.8**
Mammal	39.6	19.5	9.1	4.5		
Bird	8	1.4	5.1	1.6		
Reptile	11	1.3	48	14.3		
Amphibian	16	1.7	65	15.6	39.2	7.8
Fish	1	0.1	5.1	0.7		
Invertebrate		**53.7**		**61.6**		**90.5**
Crustacean	6	1.3	74.3	29.3	10.8	2.2
Insect	94.8	28	96	27.6	94.6	23.8
Oligochaete	66.9	24	18.3	3	100	63
Gastropod	2	0.2	17.1	1.3	1.4	
Chilopod	6	0.2	13.7	0.4	17.6	1.5
Arachnid	0.5		1.1			
Plant	**57.7**	**22.2**	**8**	**1.7**	**8.1**	**1.7**
Diet diversity		4.46		4.75		2.17

food item was calculated, based on Wise, Linn & Kennedy (1981). The volume of each food item in the faeces was estimated visually and given a score of 1–10, making the total score of all the food items found in a faecal sample 10. The relative importance of each food item in all the faecal samples collected in a month is calculated by $RI = \left[\sum(W_i \times S_i) \div \sum(W_i \times 10)\right] \times 100\%$, where W_i is the dry weight of each faecal sample, S_i is the score of each food item.

We calculated the diet diversity of each species by using the reciprocal Simpson index, $1/\sum P_i^2$ (Krebs, 1972), where P_i is the relative importance of each food item; and the diet overlap between 2 species by using $\alpha_{j,k} = \sum P_{ij} P_{ik} / \left(\sum P_{ij}^2 \sum P_{ik}^2\right)^{1/2}$ (Pianka, 1975), where $\alpha_{j,k}$ represents the degree of diet overlap between species j and k, and P_{ij}, P_{ik} are the relative importance of the i-th food item utilized by j and k, respectively.

Results

During the study period, we collected a total of 428 faeces, which included 154 from the lesser oriental civet (*Viverricula indica*), 202 from the crab-eating mongoose (*Herpestes urva*), 67 from the ferret badger (*Melogale moschata*), and five from the Siberian weasel (*Mustela sibirica*). The diet of the weasel was not analysed owing to the small number of faecal samples.

*Lesser oriental civet (**Viverricula indica**)*

We identified 12 food items from 154 civet faeces, including mammals (rodents: *Niviventer coxinga* and *Petaurista petaurista*; shrews: *Crocidura* sp.), birds (*Pomatorhinus ruficollis*), reptiles (snakes and lizards), amphibians, fish, crustaceans (crabs of the genus *Geothelphusa*), insects (locusts, grasshoppers, crickets of the order Orthoptera; tumble bugs, beetles of the order Coleoptera; termites of the order Isoptera), oligochaetes (earthworms), gastropods (snails and slugs), chilopods (centipedes), arachnids (spiders), and plant matter. Seeds of *Diospyros morrisiana*, *Elaeocarpus japonicus*, *Litsea acuminata*, *Machilus* sp., *Rubus* sp., and leaves and stems of *Miscanthus floridulus* and *Setaria palmifolia* were the plant matter identified in civets' faeces. Most of the civet faeces contained pieces of grass fragments at one end. These fragments were often not chewed, and seemed to pass through the digestive tracts almost intact.

Insect remains had the highest percentage of occurrence (94.8%) in the civets' faeces, followed by earthworms (66.9%), plants (57.7%), mammals (39.6%), amphibians (16%), reptiles (11%). The percentage of occurrence of birds, crustaceans, chilopods, gastropods, fish and arachnids were all less than 10%. Insects also had the highest score in relative importance (28%), followed by earthworms (24%), plants (22.2%), and mammals (19.5%). These four items comprised, on average, 93.7% of the faecal content (Table I). Therefore, they were the four most important food items for civets in Fushan.

The monthly variation of relative importance of different food items showed that insects were consumed more in summer, and less in winter; plant matter was consumed more in spring and summer. The importance of earthworms increased in winter; and mammals were consumed year round. Animal matter was more important than plant matter in the civets' diet in most months of the year except between March and June of 1993. However, the relative importance of plant matter was higher in the spring and early summer of 1993 than in 1994 (Fig. 1).

*Crab-eating mongoose (**Herpestes urva**)*

Although 202 mongoose faeces were collected, we analysed no more than 10 samples from each month. In months in which fewer than 10 samples were collected, all samples were analysed. The total number of mongoose faeces analysed was 174. We identified the same 12 food items found in the civets' faeces from these samples. However, a greater variety of species, which were not found in the civets' faeces, was identified in mongooses' faeces, e.g. hair of Formosan macaque (*Macaca cyclopis*), insects of the order Hemiptera, earwigs (Dermaptera), and ants (Hymenoptera), and crustacean species such as shrimps (*Macrobrachium* sp.). About 75% of the faeces contained mongoose hairs.

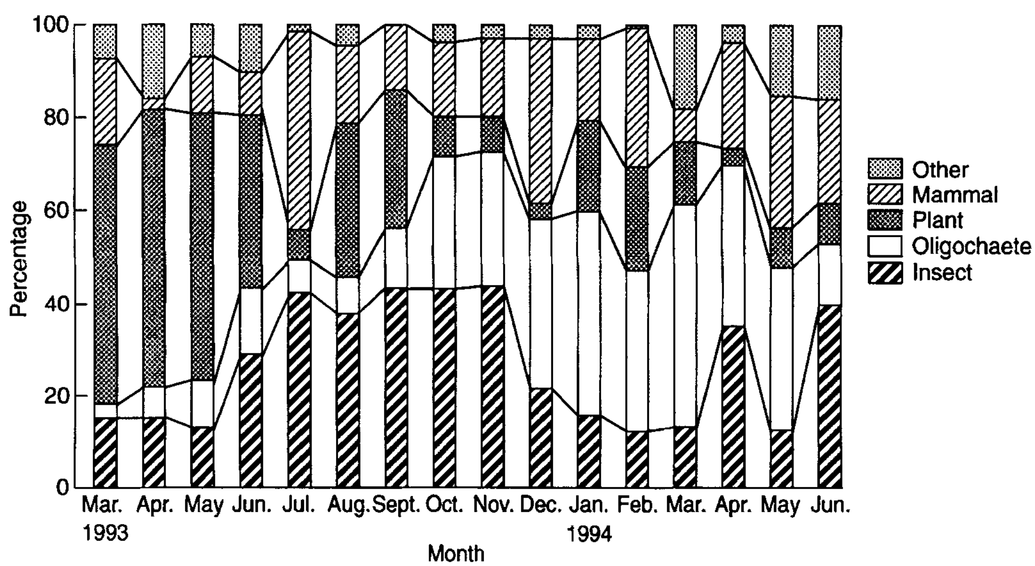

FIG. 1. Relative importance of four major food items (insect, oligochaete, plant and animal) consumed by *Viverricula indica* from March 1993 to June 1994 at Fushan Forest.

Insects had the highest percentage of occurrence (96%), followed by crustaceans (74.3%), amphibians (65%), reptiles (48%), earthworms (18.3%), gastropods (17.1%), chilopods (13.7%). The percentage of occurrence of mammals, plant, birds, fish, and arachnids were all less than 10%. Crustaceans and insects had the highest relative importance (29.3% and 27.6%, respectively), followed by amphibians (15.6%), and reptiles (14.3%). These four items comprised, on average, 86.8% of the faecal content (Table I), and were the most important food items for the mongoose in Fushan.

By comparing faeces collected from transects near the artificial pond, and faeces collected along the Ha-pen stream bed, we found that the percentage of occurrence and the relative importance of amphibians were higher in the former, whereas those of crustaceans were higher in the latter. Insects had the highest percentage of occurrence (97.9%) in the faeces collected near the pond, followed by amphibians (89.4%), crustaceans (51.1%), and reptiles (44.7%). The relative importance, however, was the highest in amphibians (34.9%), followed by insects (26.2%), reptiles (11.6%), and crustaceans (8.6%). Of the faeces from the stream bed, the percentage of occurrence from high to low was insects (92.3%), crustaceans (82.7%), amphibians (43.2%), and reptiles (43.2%); and the relative importance of these four food items from high to low was crustaceans (34.0%), insects (32.1%), amphibians (10.7%) and reptiles (5.8%) (Fig. 2).

The monthly variation in the relative importance of different food items showed that the mongooses ate more insects in summer and autumn, more crustaceans in winter, and more reptiles in late spring and early summer (Fig. 3).

*Ferret badger (**Melogale moschata**)*

Of the 67 ferret badger faeces collected, 64 were analysed, and only seven food items were found in these samples. Mammals, birds, reptiles, and fish were not found in these faeces, which means that

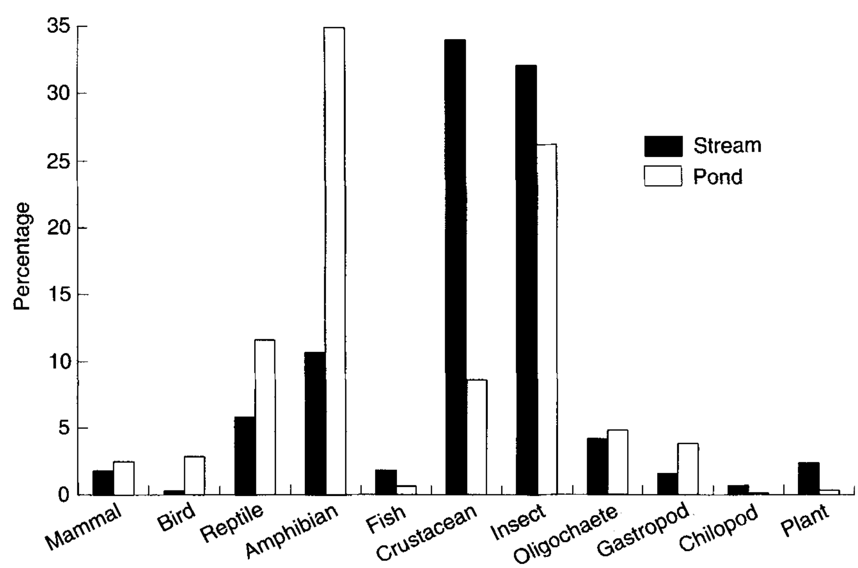

FIG. 2. Differences in the relative importance of different food items in *Herpestes urva* faeces collected near a pond versus along a stream at Fushan Forest.

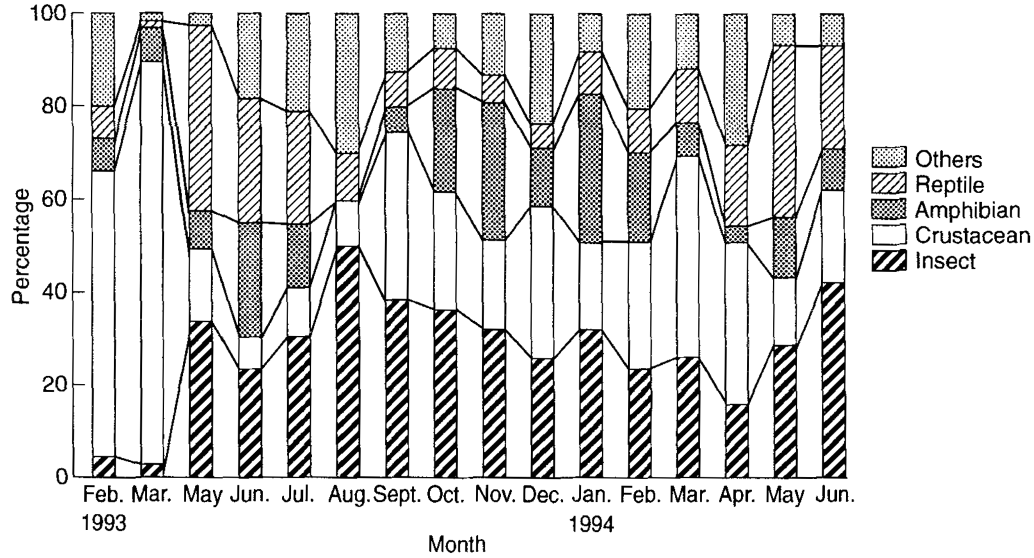

FIG. 3. Relative importance of four major food items (insect, crustacean, amphibian and reptile) consumed by *Herpestes urva* from February 1993 to June 1994 at Fushan Forest.

ferret badgers consumed mainly invertebrates, amphibians, and plants. Insects of the order Lepidoptera, Orthoptera, Coleoptera, Isoptera, Dermaptera, Hymenoptera, and Hemiptera, shrimps and crabs, snails, centipedes, and some plant species (*Ficus* sp.) were found in the faeces.

Among the food items consumed by ferret badgers, earthworms (PO = 100%, RI = 63%), insects

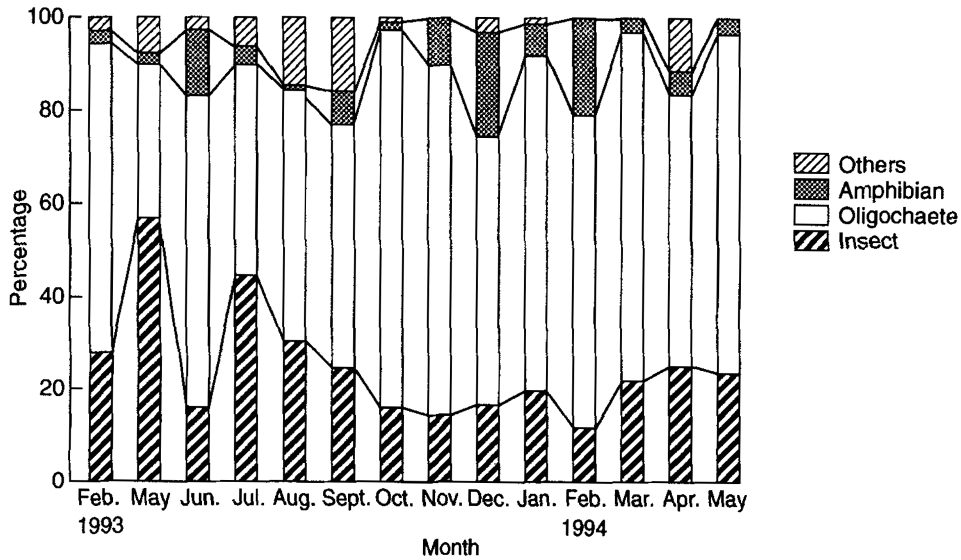

FIG. 4. Relative importance of three major food items (insect, oligochaete and amphibian) consumed by *Melogale moschata* from February 1993 to May 1994 at Fushan Forest.

(PO = 94.6%, RI = 23.8%), and amphibians (PO = 39.2%, RI = 7.8%) were the most important (Table I).

The monthly variation of the relative importance of different food items showed that ferret badgers ate earthworms and insects almost year round. However, more insects were eaten in summer than winter, more earthworms in winter than summer, and more amphibians appeared in the faeces in late autumn and early winter (Fig. 4).

Diet diversity and degree of diet overlap

All three carnivore species in this study consumed a large number of insects. Civets and ferret badgers also consumed a lot earthworms, whereas mongooses and ferret badgers ate a higher proportion of amphibians. Civets consumed a higher proportion of plant material which was scarcely eaten by mongooses and ferret badgers. Civets and mongooses ate more vertebrates than did ferret badgers. The diversity of diet was the highest in mongooses (4.75), followed by the civets (4.46), and the ferret badgers (2.17) (Table I).

The degree of overlap in diet was greatest between the civet and the ferret badger (0.69), followed by that between the civet and the mongoose (0.49). Mongoose and ferret badger had the lowest degree of diet overlap (0.34). The degree of diet overlap between these species varied in different seasons (Fig. 5). The degree of diet overlap between civet and ferret badger were almost always greater than 0.5 except in the spring of 1993 when the civet consumed more plant matter. The degree of diet overlap between mongoose and ferret badger was almost always less than 0.5 except in May and July of 1993 when both species consumed more insects. The diet overlap of the three species was the highest in summer when all of them ate a greater amount of insects. However, only the seasonal variation of diet overlap between civet and mongoose showed a significant trend of higher overlap in summer and autumn, when both species consumed more insects, than in winter and spring (Wald-Wolfowitz Runs Test, $z = -2.782$, $P = 0.005$).

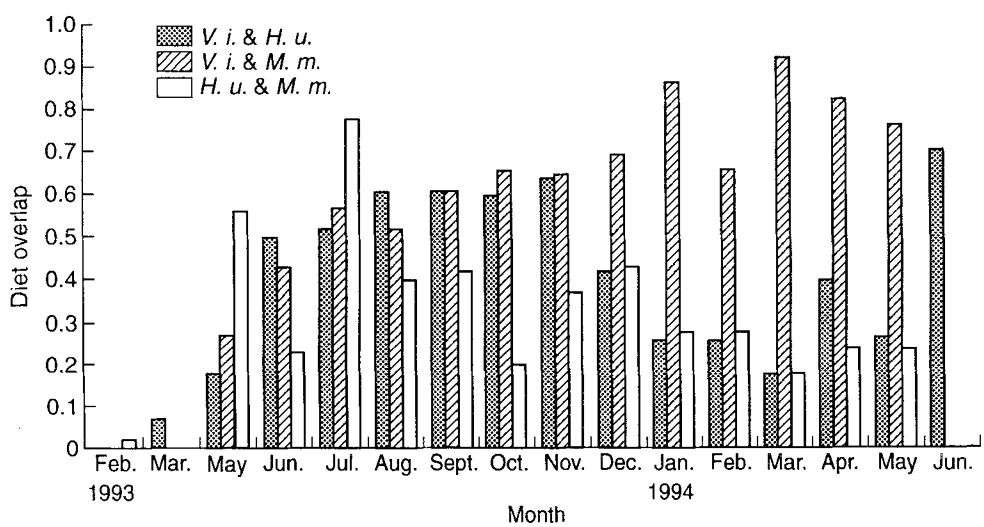

FIG. 5. Changes in the degree of dietary overlap among *Viverricula indica*, *Herpestes urva*, and *Melogale moschata* from February 1993 to June 1994 at Fushan Forest.

By grouping all the food items consumed by these carnivores into three categories: vertebrate, invertebrate, and plant, we concluded that all three carnivore species ate more invertebrates (RI = 53.7%, 61.6%, 90.5% in the diet of civet, mongoose, and ferret badger, respectively) than vertebrates and plants. Therefore, invertebrates play a very important role in the food web of Fushan Forest ecosystem.

Discussion

The food items found in lesser oriental civets' faeces covered a large portion of the major animal taxa, and several plant species in Fushan, which indicated that this civet is an omnivore and a generalist. This result is similar to previous reports (Lekagul & McNeely, 1977; Ayyadurai *et al.*, 1987; Gao *et al.*, 1987; Nowak, 1991). However, Wang *et al.* (1976) analysed the contents of 64 civet stomachs in mainland China, and reported that rodents had the highest percentage of occurrence (79.7%), followed by plants (46.8%), insects (23.4%), and frogs (15.3%), which was very different from the results of faecal analysis in this study where civets ate more insects and earthworms than rodents. This result may reflect the low availability of rodents, especially rats (*Niviventer coxinga*) in the study site (Lee, 1994).

Although earthworms were frequently found in civets' faeces in this study, they were hardly mentioned in other relevant literature (Lekagul & McNeely, 1977; Ayyadurai *et al.*, 1987; Gao *et al.*, 1987; Nowak, 1991). Only Nowak (1991) reported that some close relatives of lesser oriental civets will eat earthworms. Whether this difference is due to the difficulty in identifying the small chaetae of earthworms, and so their presence was ignored in other studies, or due to diet difference because of local food availability, is worth further investigation.

The fact that most civet faeces contained grass fragments was also reported by Gao *et al.* (1987). These fragments are low in nutrition, and often little digested, therefore, grass is unlikely to be an important food source for energy or nutrition. We found on a few occasions that there were endoparasites, e.g. hookworm (Ancylostomatidae) and roundworm (Ascarididae) in the grass. Some research also indicated that some mammals may ingest grass or leaves to clear up the endoparasites, or cure certain diseases (Newton, 1991). This may imply a similar reason for civets to ingest grass fragments.

Mongooses also eat a great variety of food items (Gao *et al.*, 1987; this study). However, by comparing the samples collected from different areas, i.e. the pond versus the stream, one can see that the composition of diet may vary due to changes in food availability. Seasonal variation in diet also reflected the same trend.

The ferret badgers have the narrowest food niche of all the carnivore species we studied. However, previous studies reported that they also eat rodents, birds, reptiles, amphibians (Gao *et al.*, 1987). Chien *et al.* (1976) analysed the stomach contents of 60 ferret badgers on the mainland and reported that earthworms had appeared in the sample more often than other food items (43.3%). However, this percentage is much lower than our results. These differences may again be due to the difference in food availability in different study sites.

Although food availability was not measured in this study, other studies conducted in Furshan reported that insect abundance increases in summer and autumn, whereas crustaceans are more abundant in winter (Huang, 1995), and more plant species fruit in spring (Kuo, pers. comm.). Such results coincided with the seasonal variation in the diet of the three carnivore species, and in dietary overlap among them. Civets ate more plant material in spring, monogooses ate more crustaceans in winter and early spring, all three species ate more insects in summer and autumn, and the degree of dietary overlap between civets and mongooses was significantly higher in summer and autumn when both species ate more insects.

The dietary overlap among these three carnivores was much greater between the civets and ferret badgers, which was almost always greater than 0.5 year round, than between the civets and mongooses, or between the ferret badgers and the mongooses. However, since the calculation of dietary overlap was based on the relative importance of 11 animal classes and plants in these animals' diets, and different species of food items belonging to the same animal class may be consumed by different carnivores, the actual differences in diet between these species may be greater and overlap less if all the food items in this study could have been identified to the species levels.

The results of this study indicate that invertebrates, especially insects, crustaceans and earthworms, play a very important role in the food web of the Fushan Forest ecosystem.

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