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Food composition and food niche overlap of three kinds of canidae

Hong-Hai Zhang [a,*], Xin-Ping Liu [a], Hua-Shan Dou [b], Cheng-De Zhang [a], Ying Ren [a]

[a] College of Life Science, Qufu Normal University, Qufu 273165, China
[b] Dalai Lake Nature Reserve, Hailar 021000, China

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ABSTRACT

The diets of the wolf *Canis lupus*, red fox *Vulpes vulpes* and raccoon dog *Nyctereutes ussurienusis Matschie* were studied in the grassland of eastern Inner Mongolia from August to October in 2007 and from March to July in 2008. Feces were collected from dens and latrines. The frequency of occurrence and the dry weight of the remains of each food item in the feces were calculated. Livestock (50.65% frequency of occurrence) constituted the bulk of the wolf diet, while small rodents (76.31% frequency of occurrence) were most frequently eaten by the foxes. Small rodents (22.69% frequency of occurrence) were important to the raccoon dogs but they also frequently consumed birds (39.81% frequency of occurrence) and insects (26.39% frequency of occurrence). The wolf was the most omnivorous and the red fox was the least omnivorous of these three kinds of canidae according to the diversity index. The food niches of the wolf and the red fox overlapped more than that of the raccoon dog and other species. These three kinds of canidae shared many resources and consequently competition occurred to them. However, their diets also differed to some extent which helped them to avoid competition. Furthermore, raccoon dogs were dormant in winter when food was scarce, which may be the reason why all these species could coexist in a rather unproductive grassland.

1. Introduction

The diets of animal are the core content of the study on the habitat demand. The analysis on them can provide valuable basic information for the work of evaluating the habitat, estimating the carrying capacity and studying the energy metabolism and the interspecific relation. Meanwhile, it provides academic basis for protection on the carnivore especially the endangered species, artificial breeding and resource management [1]. Wolf, red fox and raccoon dog are three kinds of canine predator which inhabit in the grassland of eastern Inner Mongolia [2]. They are on the top of the food chain, so they play an important role in energy flow and material cycle of the ecosystem. According to the research on the wolves and red foxes which live in the grassland of eastern Inner Mongolia, breeding caves of wolves generally lie in the arid reed field while those of red foxes often lie in the willow shrub, but they overlap a lot on the cave niche [3–5]. Raccoon dogs often inhabit the jungle, reed field and the wild grass ground which is near a river or a lake [6] and they usually use the discarded caves of red foxes or others. So these three kinds of carnivore overlap on the space distribution to some degree. They distribute over the same area and some kind of them may prey on the others. Zhong-Xin et al. [7] had found relict of red foxes in the cave of wolves at Xin Barag Youqi. Zhong-Xin et al. [7] and Wen-Bo et al. [8] did some research on local wolves and they found that small rodents were the secondary food wolves choose but were steady food resources. Red foxes and Raccoon dogs fed chiefly on small rodents [9–15]. At the present time, few people have done systematic research about the food niche overlap of these there kinds of canidae. Accordingly researches on the diets of these three kinds of canidae are helpful for accumulating basic data and offer scientific basis for the protection and management on them.

2. Study area

Dalai Lake Natural Reserve lies in the northeast of Inner Mongolia and the west of Hulunbuir. The latitude is 47°45′50″N–49°20′20″N, 116°50′10″E–118°10′10″E. This Natural Reserve covers 740,000 hm^2 and it is temperate continental climate here where there is little rain but so much wind. The annual mean temperature is 0.3 °C, and it can be up to 40 °C in July and low to −43 °C in January. Low mountain-hill, fluvial plain and lowland near rivers or lakes compose the main terrain here. There are plentiful animal and plant resources. Typical grassland vegetation, sand vegetation, saline meadow, swamp vegetation and meadow vegetation are visible here. Animal resources include birds, fishes, insects, mollusca and so on.

* Corresponding author.
E-mail address: zhanghonghai67@126.com (H.-H. Zhang).

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3. Methods

3.1. Collection of feces

From August to October of 2007 and from March to July of 2008, utilizing snowfield tracking and sandy land tracking, feces of these three kinds of canidae were collected beside their caves and footprint chain and then put in the freshness protection packages. The feces were air dried for preservation. These three kinds of feces can be distinguished from the others easily due to the diameter and length of feces of wolves being bigger than those of red foxes and raccoon dogs and defecation places of raccoon dogs being steady while those of raccoon dogs being always beside the caves and fresh marks.

3.2. Experimental analysis

The diets of these three kinds of canidae were analyzed by methods of frequency of occurrence and relative dry weight of remains [16,17]. Feces were dried in the drying oven for 72 h at 80 °C and then weighed and measured. They were separated detailedly by tweezers and dissecting needles in dry condition. Different components such as hair of animals, feather of birds, skeletons, teeth, skull, claws, insect pieces and plant seeds were separated and their dry weight was weighed by electronic balance respectively (accurate to 0.1 g). Hair and feathers collected were observed under the 10 times magnifying glass and then the length, thickness, shape and color of each feather were recorded. Squashes of hair flake were observed under the 200 times optical microscope. They were compared with samples of hair collected there and normative manual of mammal hair, and then the type of food could be ascertained. Species of the birds and small rodents were not identified. All of the identification process was done by one person independently and the person who did the identification was blind tested by two samples (the number of the samples was 60 and 50, respectively). The accuracy was 99.17% and 99.13%, respectively.

3.3. Data processing

Since the majority of fecal samples contained two or more types of food, relative frequency of occurrence was recorded to count the frequency of occurrence of each food type. That is, if any one kind of food was found in the fecal sample, the frequency of occurrence was defined as one time. After the summary, the percentage of frequency of each food type in total frequency of occurrence was the data we need. In the method of relative dry weight of remains, remains of prey of non-mammals separated directly were weighed as the dry weight. But for mammals, the dry weight of remains separated directly, remains not separated and hair of mammals were weighed, respectively, and the summation of them was the dry weight of remains. Spearman rank correlation test was done to the order of different kinds of food got by these two methods.

FNB (food niche breadth) was calculated by Shannon–Weiner index.

$$\mathrm{FNB} = -\sum_{i=1}^{s} P_i \log_2 P_i$$

FNB means the food niche breadth of species i and P_i means the frequency of occurrence of species i in the diet of predator. The larger the numerical value of FNB, the wider the food niche breadth.

Food niche overlap index was calculated by Pianka index.

$$C_{ik} = 1 - \frac{1}{2}\sum |N_{ij}/N_i - N_{kj}/N_k|$$

C_{ik} means food niche overlap index of species i and species k. N_{ij} and N_{kj} mean the frequency of occurrence of species j in diets of predator i and predator k, respectively. N_i and N_k mean the numerical value of species i and species k in all of the resource degree. C_{ik} ranges from zero to one. When C_{ik} equals zero, there is no food niche overlap between species i and species k. When C_{ik} equals one, there is a complete overlap between species i and species k.

The data was analyzed by SPSS 13.0.

4. Results

4.1. Food composition of three kinds of canidae

From August to October of 2007 and from March to July of 2008, 59 fecal samples of wolves, 124 fecal samples of red foxes and 134 fecal samples of raccoon dogs were collected in Dalai Lake Natural Reserve in Inner Mongolia.

From the analysis, we found that livestock constituted the bulk of the wolf diet and small-sized animal were the secondary food including hares, rodents and birds. Insects, plants and garbage played a relative smaller part in the diet of wolves (Table 1).

Small rodents constituted the bulk of the diet of red foxes while the proportion of other kinds of food in the diet is smaller (Table 2).

Raccoon dogs fed chiefly on birds and rodents, and insects, plants, fishes and shrimps were the secondary food. The proportion of mollusks in the diet is the smallest (Table 3).

Table 1
The food composition of wolf.

Species	Occurrence	Frequency (%)	Dry weight of remains (g)	Percentage (%)
Horses	3	3.90	24.0	1.18
Cattle	8	10.39	320.8	15.72
Sheep and goats	28	36.36	1017.7	49.86
Hares	3	3.90	162.8	7.98
Birds	7	9.09	124.7	6.11
Small rodents	18	23.38	320.6	15.71
Insects	1	1.30	34.6	1.70
Plants	7	9.09	30.4	1.49
Garbage	2	2.59	5.4	0.26
Total	77	1	2041.0	1

Table 2
The food composition of red fox.

Species	Occurrence	Frequency (%)	Dry weight of remains (g)	Percentage (%)
Cattle	1	0.66	18.0	2.12
Sheep and goats	4	2.63	21.7	2.56
Hares	3	1.97	49.5	5.84
Birds	7	4.61	13.8	1.63
Small rodents	116	76.31	714.4	84.24
Insects	2	1.32	1.1	0.13
Plants	9	5.91	16.4	1.93
Fishes	6	3.95	9.0	1.06
Shrimps	2	1.32	2.1	0.25
Garbage	2	1.32	2.0	0.24
Total	152	1	848	1

Table 3
The food composition of raccoon dog.

Species	Occurrence	Frequency (%)	Dry weight of remains (g)	Percentage (%)
Birds	86	39.81	813.40	52.60
Rodents	49	22.69	399.70	25.85
Insects	57	26.39	206.00	13.32
Plants	16	7.41	21.50	1.39
Fishes	5	2.31	89.50	5.79
Shrimps	2	0.93	13.20	0.85
Mollusks	1	0.46	3.00	0.20
Total	216	100	1546.3	100

Table 4
Spearman order index of prey in the diets of wolf, red fox and raccoon dog with frequency method and relative dry weight of remains method.

Predator	Number of food item	Spearman order index Frequency vs relative dry weight of remains
Wolf	9	0.773*
Red fox	10	0.460
Raccoon dog	7	0.929**

* $p < 0.05$.
** $p < 0.01$.

4.2. Food niche breadth and overlap index of three kinds of canidae

Food niche breadth of three kinds of canidae were calculated by Shannon–Weiner index as follows:

Food niche breadth of wolves was 1.0752;
Food niche breadth of red foxes was 0.0744;
Food niche breadth of raccoon dogs was 0.9103.

Food niche overlap index of three kinds of canidae were calculated by Pianka index as follows:

Food niche overlap index of wolves and red foxes was 0.4277;
Food niche overlap index of wolves and raccoon dogs was 0.4049;
Food niche overlap index of red foxes and raccoon dogs was 0.3777.

4.3. The difference between frequency of occurrence and relative dry weight of remains

The diets of these three kinds of canidae were studied and analyzed by methods of frequency of occurrence and relative dry weight of remains. In order to see whether there were any differences between the results from two methods, Spearman rank correlation test was done to the order of different kinds of food got by these two methods (Table 4). The conclusion was that there were no significant differences between the two methods when they were used to analyze the diets of wolves and raccoon dogs but it was opposite for that of red foxes. We guessed it was because red foxes fed excessively on small rodents (the frequency of occurrence was up to 76.31%) and there was a big contingency in the order of other kinds of food. Namely, red foxes mostly preyed on these kinds of food by chance.

From the result of the method of frequency we can see that this method can reflect well which kinds of food the predator prey on and the times the predator prey on them. But the method of frequency sometimes overestimates the small food types such as insects, thus the importance of large food types is underestimated. In the method of relative dry weight of remains, the part which cannot be digested needs analyzing and the importance of each kind of food in the diet of the predator can be reflected. But as the predator has different digestibility for different food types, dry weight of remains in the fecal samples cannot clearly reflect how much food the predator has eaten.

5. Discussion

5.1. Food composition of three kinds of canidae

In this study, remains of wild ungulate such as Mongolian Gazelle were not found in fecal samples of wolves. Livestock such as horses, cattle and sheep (50.65% frequency of occurrence) constituted the bulk of the wolf diet. There may be two reasons which cause the difference. On one hand, wild ungulate here especially Mongolian Gazelle being in danger of extinction was the main reason; on the other hand, the number of the livestock was so large that living space of wolves was extruded by over grazing. At the same time, management mode for the livestock was an important reason why wolves preyed on livestock.

Small rodents constituted the bulk of the diet of red foxes while wild ungulate were not found. The frequency of occurrence of livestock was also at a low level. Physiological characteristics and foraging strategy of red foxes determined that they could not prey on large ungulate such as horses and cattle. And sheep and goats were generally in charge of the shepherd so that red foxes seldom preyed on the ungulate and they only fed on the corpse of dead livestock by chance.

Being a kind of omnivorous animal, raccoon dogs had many choices of food. Small rodents, birds, plants and insects were often found in their diets. Besides, fishes, shrimps and mollusks also fell prey to raccoon dogs sometimes. Remains of avian eggshell were discovered near the caves of raccoon dogs. Accordingly, we believed raccoon dogs also eat avian eggs though remains of avian eggshell were not found in the feces.

5.2. Food niche breadth and food niche overlap index of three kinds of canidae

From the food niche breadth of three kinds of canidae, we can see the food niche breadth of wolves was the largest and the range of food types was also the widest. The diet of wolves included many species from large ungulate such as horses and cattle to small rodents or insects. The food niche breadth of raccoon dogs was second to wolves as they were omnivorous. The food niche breadth of red foxes was the least and they could only prey on small-sized food types because they had neither the ability to prey on large ungulate nor omnivory.

According to the food niche overlap index of three kinds of canidae, the food niche overlap index of wolves and red foxes was larger than the others. We can find the food types they preyed on were similar but frequencies of feeding on each food type were significantly different. Wolves preferred large or middle-sized animals when red foxes preyed chiefly on small-sized food types, so there were essential differences between main food types of the two though they overlapped to some degree on feeding on small rodents. Wolves sometimes preyed on red foxes in their home range but it did not influence the coexistence in the grassland. The food niche overlap index of red foxes and raccoon dogs was the least. Red foxes preyed chiefly on rodents while raccoon dogs preferred birds, insects and plants though rodents were also important food resources of raccoon dogs. That was similar to the research results in Europe: red foxes and raccoon dogs overlapped to some extent on food niche. Red foxes generally fed on middle or small-sized mammals like rodents and so on. Raccoon dogs also preyed on rodents but they had other food resources (birds, insects, fishes, plants, etc.) which were more important. Besides, raccoon dogs were dormant in winter when food was scarce, and that avoided the conflict between raccoon dogs and red foxes.

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