

Diet of the Chinese Water Deer (*Hydropotes inermis*) in Zhoushan Archipelago, China

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Abstract: This study was to determine what kind of feeders the Chinese water deer are in Zhoushan Archipelago, China. The study was conducted by using observation of feeding signs in the wild, microhistological analysis of feces, and feeding trials. The results showed that Chinese water deer fed on a total of 137 plant species, included in 61 families and 115 genera. Leguminosae plants were selected most, both in numbers of species and frequency of occurrences. Even though they maintained a relatively constant usage level of plant species and families, the numbers of both decreased from spring to winter, but diet in summer and autumn were similar to that in spring. All of the four plant types (forbs, graminoids, woody plants and forbs) were taken year-round with no significant differences, even though they were varied among seasons, however all types except woody plants showed significant variation among seasons. Herbage intake decreased while that of woody plants increased, from spring to winter. Woody plants and forbs were dominant, while graminoids were rare in the diet of the deer. The results suggested that the Chinese water deer is a concentrate feeder or a browser in Zhoushan Archipelago, Zhejiang Province, China.

Key words: The Chinese water deer (*Hydropotes inermis*); Microhistological analysis of feces; Feeder type; Seasonal changes

舟山群岛獐的食性研究

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摘要: 利用野外观察、粪便显微组织学分析和投喂实验等方法对舟山群岛獐的食性进行了研究。结果表明, 研究地的獐所食植物共有 137 种, 隶属于 61 科 115 属, 其中豆科植物在取食种类和取食频次上均多于其它科植物。尽管獐对植物科和种的选择在四季间没有显著差别, 但取食科和种的数量依然从春天到冬天呈递减趋势, 并且冬天与其它 3 个季节差别较大。獐的食物中, 每个季节都含有非禾草类草本植物、禾草类草本植物、木本植物和蕨类植物, 且其食物组成在季节间亦无显著差异; 除木本植物外, 獐对其它 3 类植物的选择在季节间有显著差异。獐在冬天较多选择木本植物, 而其它季节较多选择草本植物, 但木本植物和非禾草类草本植物在四季食物组成中均占较高比例, 而禾草类植物所占的比例很小。因此, 笔者认为舟山群岛的獐应该偏向于嫩食者。

关键词: 獐; 粪便显微组织学; 取食类型; 季节变化

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1 Introduction

The digestive system of ruminants may be classified into 3 main categories: (1) concentrate feeders, which feed mainly on the foliage of trees, shrubs, or forbs; (2) bulk and roughage feeders, which feed predominantly on

grasses; and (3) intermediate or adaptable mixed feeders, which either browse or graze depending on what is locally available (Hofmann, 1973). Intermediate feeders tend to be grazers during periods of high resource availability in the spring and summer in temperate regions or in the wet seasons in tropical regions (Jarman, 1971; Jar-

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man and Sinclair, 1979; Gordon and Illius, 1988). The digestive strategies of browsers or grazers are different. Browse contains indigestible material in the cell wall, mainly lignin and structural carbohydrates (such as hemicellulose and probably cellulose that are bound to it), but more digestible material within the cell as compared to grass. Little benefit was gained from retaining browse in the rumen for lengthy periods because lignin is highly indigestible. Browsers, therefore, maximize the extraction of the digestible cell contents by having a short period of digestion in order to process as much as possible. Alternatively, grazers have longer retention times to facilitate fermentation of the cellulose in the cell wall (Van Soest, 1980, 1982). The optima for selective and nonselective feeders differ for two reasons. Firstly, the consumption frontier depends upon body size, feeding apparatus, and digestive capability of each herbivore for the two forage classes. Secondly, the relative value of forages depends upon specific digestive adaptations (Hudson, 1985). Most cervidae are either concentrate feeders (e.g. moose *Alces alces*), roe deer (*Capreolus capreolus*), and muntjac (*Muntiacus* spp.) or mixed feeders (e.g. red deer *Cervus elephas Canadensis* and *C.e.elaphus*, reindeer *Rangifer tarandus tarandus*, caribou *R.t.arcticus*), and fallow deer (*Dama dama*) (Key *et al.*, 1980). The Chinese water deer was also classified by Hofmann *et al.* (1988), according to the morphological criteria and their digestive system, as a concentrate selector approaching an intermediate position. Hudson (1985) said that most ungulates weighed less than 50 kg and were selective feeders, so the water deer should be a selective feeder for its weight of 10 – 15 kg (Xu, 1981; Sheng, 1992). Zhang (2000) suggested that it is possible therefore that the Chinese water deer should not be regarded as mainly a grazer although at Whipsnade it fed almost only on grasses. It has also been classified by Cook and Farrell (1998) on the basis of gut anatomy as being a concentrate selector but the studies on its food do not completely support this supposition as grasses and similar species contribute a considerable proportion of its diet.

This paper aims to study the diet of the Chinese wa-

ter deer (*Hydropotes inermis*) and to determine what kind of feeder the Chinese water deer is in Zhoushan Archipelago.

The Chinese water deer is believed to be the most primitive member of the family Cervidae. It is only distributed in China and Korea Peninsula, although it was introduced to England in 1930's, and France in 1954. Many individuals escaped from the Duke of Bedford's Woburn Park in England and established a wild-living population (Sheng, 1992; Cook and Farrell, 1998). It has been listed in the second category of the Chinese State Key Protected Wildlife List and as an LR/nt species under the IUCN Species Category. It was once widely distributed at latitude between 28° – 42°N, and between longitude 111°E and the western coast of Pacific and it had been considered as abundant animal over much of China. Nonetheless, its distribution was decreased greatly because of habitat destruction and over-hunting in recent years, and it is now localized mainly in four fragmental areas (Sheng, 1992; Zhang and Guo, 2000; Guo and Zhang, 2002).

2 Study area

Zhoushan Archipelago is located in the east of China (29°32' – 32°04' N, 121°31' – 123°25' E) with 1 384 isles and it is the largest archipelago in China. The climate is south of northern subtropical monsoon maritime climate with mean annual temperature of 16.1°C with an annual precipitation of 587 – 874 mm. The vegetation belongs to the northern region of mid-subtropical evergreen broad-leaved forest with vegetation coverage of 74.3% and forest coverage of 39.34%. There are 1 602 plant species belonging to 795 genera of 186 families, which formed very complex vegetation types. The main plant species of grasses and shrubs are *Kalimeris indica*, *Rumex acetos*, *Imperata cylinderaca*, *Lespedeza bicolor*, *Vaccinium bracteatum*, *Eurya japonica* (Insular Vegetation Resources Investigating Group of Zhoushan Forest Bureau, 1999). The main plant families are Gramineae, Compositae, Leguminosae, Labiatae, Rosaceae, Liliaceae, Cyperaceae, Rubiaceae, Umbelliferae, Euphorbiaceae according to the predominance of the number of

their genera (Jin *et al.*, 1991). There are a total of 18 large or middle sized mammals species, the Chinese water deer and the Chinese muntjac (*Muntiacus reevesi*) are common and of the largest sized ones (Insular Vegetation Resources Investigating Group of Zhoushan Forest Bureau, 1999).

3 Materials and Methods

3.1 Observation of feeding signs in the wild

It is practical to collect plants eaten by water deer following the chains of their footprints to their feeding or bedding sites, because there is no livestock herding and no other wild similar body sized herbivores around except Chinese muntjac which are distributed only in three islands (Sheng, 1992). At feeding sites, the traces of the deer, such as hair, pellet, or footprint should be confirmed. Specimens of the plant species were collected and identified by a botanist in the laboratory.

3.2 Microhistological analysis of feces

3.2.1 Making reference samples of epidermis from diet plants in the study area: 127 plant species including the bitten ones were collected and cut into small pieces and macerated with nitric acid in tubes individually to get their epidermis. Then the contents were rinsed and the plant fragments were transferred to a centrifuge tube, drained and dyed with an alcoholic solution of gentian violet. After 30 min the tubes were topped up with 70% alcohol and changed 2–3 times with upgraded alcohol and the final change was done in absolute alcohol until excess dye was removed. Changes were facilitated by centrifuging the tubes so that the solids were sufficiently packed at the bottom for the tubes to be safely inverted for draining. Then the contents were poured into a petri dish whence epidermis was transferred to slides by each species and smoothed by gently stroking with a brush. After removing excess alcohol with blotting paper, they were finally mounted in euparal (Storr, 1961). Each sample slide was observed, described and photographed by its characters of epidermal cells, stomata or trichomes under high power ($100\times$). There were total 204 photos taken and sorted by their classification (Fig. 1). Every character of fragments was measured with a graticule with $1\text{ mm}\times 1\text{ mm}$

grid fitted in the right ocular and a micro-gauge with 0.05 mm unit of length in the left ocular. The items observed and measured include ordinary epidemical cell (shape, characters of vertical cell wall, density or size), stomata (type, figure, density, size, and characters of subsidiary cells), trichomes (single cell or multi-cell, length, diameter, density, location [on venation or not], surface character, and cells around it) (Storr, 1961; Litvaitis *et al.*, 1996).

3.2.2 Preparation and analysis of composite samples of pellets: a total of 93 fresh or recent pellets were collected in four seasons and in 14 islands from July 1999 to June 2000. All pellets were stored in bottles for subsequent laboratory analysis. 2 pellets / pile were taken out, pooled by season and first dried and thoroughly ground to make composite samples. Seasonal composite samples consisted of pellets from ≥ 10 defecations (Green, 1987). Then the samples were macerated following the above steps. Since fecal residues absorbed more dye, one or two additional changes of alcohol were conducted to remove the excess (Storr, 1961). Finally they were temporarily mounted on slides for analysis.

3.2.3 The slides were observed at a magnification of $100\times$ by systematically traversing the zones and 20 fields of view were examined in each slide. Meanwhile, the fragments were identified according to the reference photos of sample plants and at least 10 slides from each season were examined.

3.3 Feeding experiment: selecting 39 plants including forbs, woody plants and ferns to feed the water deer at a local captive breeding center where there were 4 male and 12 female adults.

3.4 All data were processed with SPSS 10.0 and Origin 6.1.

4 Results

4.1 Result of observing feeding signs in the wild

There were a total of 121 species belonging to 55 families and 99 genera found taken by the water deer in study area. There are 14 species each of Leguminosae and Compositae, 5 species of Labiatae and Cruciferae, and 4 species of other four families individually which species of

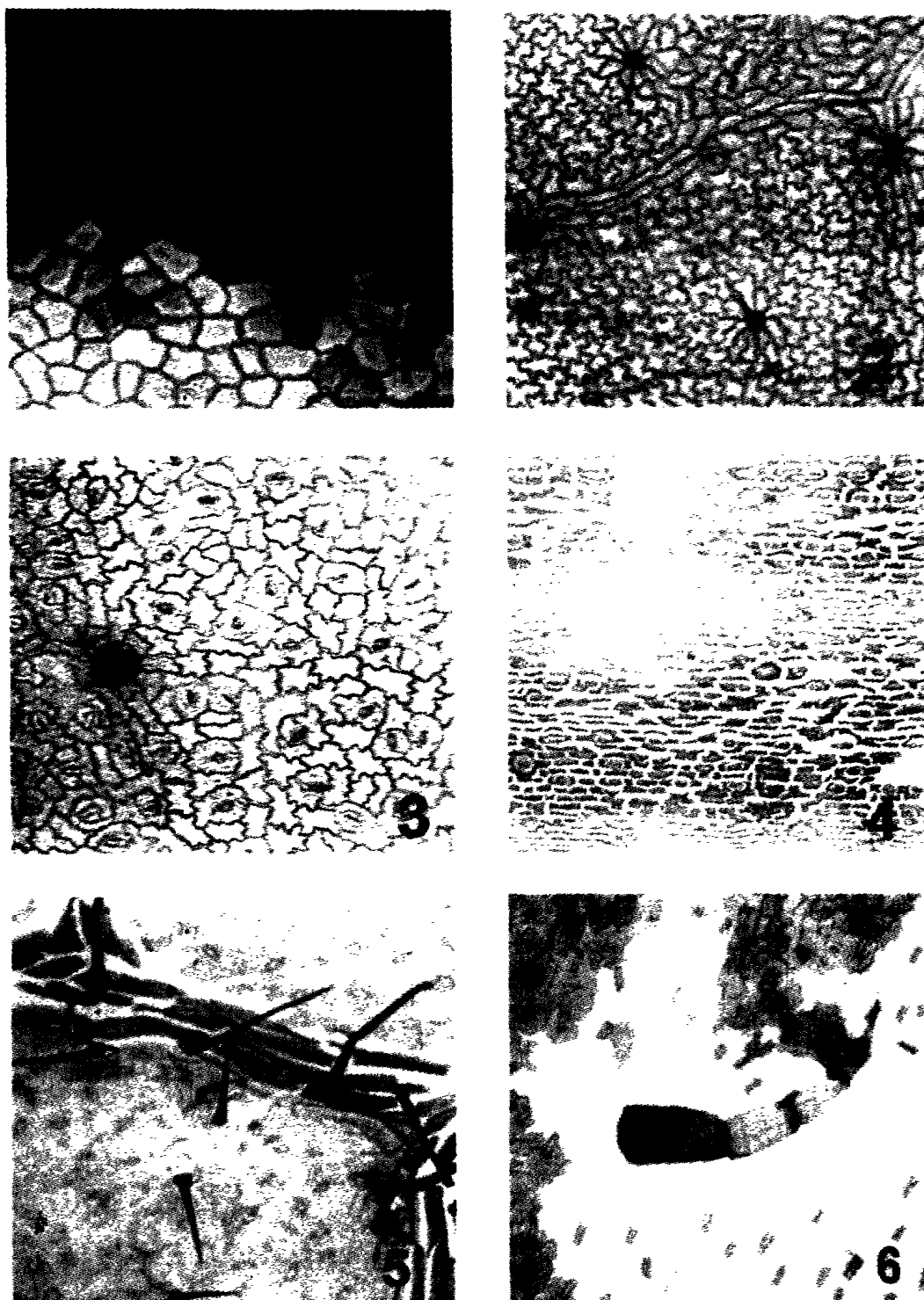


Fig.1 Characteristics of different structures on epidermis in different plants

Photo 1 and 2: showing difference between straight cell wall (e. g. *Vaccinium bracteatum*) and wavy cell wall (e. g. *Albizia kalkora*);

Photo 3 and 4: showing difference between stomatas of dicotyledon (e. g. *Ardisia japonica*) scattered on the surface epidermis and monocotyledon (e. g. *Juncus effusus*) arraying nearly in rows paralleling the venation;

Photo 5 and 6: showing difference between single cell trichomes (e. g. *Rubus swinhoei*) and multi-cell trichomes (e. g. *Scutellaria guillemii*).

these 8 families (14.54% of the total) consists of 45.00% of all plants bitten by the deer. Most of the bitten species

(59.51%) were forbs, meanwhile 29.75% were woody plants and also 8.26% ferns, but only 2.48% were

graminoids. Leaves, especially tender leaves, were the main selection by water deer. It is found that 58.97% of the stems of herbage, usually about 5 cm from the top of plants were bitten, while 35.9% of woody plant stems were bitten but also on the tip of the branch. Also flowers of 9 species and fruits of 3 species were found bitten by the deer. Some cultivated species, such as peanut (*Arachis hypogaea*), sweet potato (*Ipomoea batatas*), rice (*Oryza sativa*) and peas (*Pisum sativum*) were taken even adjacent to the village houses. Stomach of a water deer was examined and it was filled almost with rice. It means water deer sometimes visit paddy fields to feed on crops.

4.2 Result of Microhistological analysis of feces

There were 81 plant species belonging to 43 families and 68 genera identified with some unknown ones by this method. Even though the deer maintained a relatively constant usage of plant species and families among seasons ($\chi^2 = 5.55$, $df = 3$, $P = 0.14$ of species and $\chi^2 = 4.57$, $df = 3$, $P = 0.26$ of families), the number of both decreased from spring (57 species and 42 families) to winter (35 species and 26 families), but summer (52 species and 39 families) and autumn (50 species and 37 families) were similar to that of spring.

All four plant types (forbs, graminoids, woody plants and ferns) were eaten year-round but they were variable with no significant difference among seasons ($\chi^2 = 0.375$, $df = 3$, $P = 0.945$). However all types except woody plants ($\chi^2 = 5.05$, $df = 3$, $P = 0.168$) showed significant variations among seasons (the significances for forbs, graminoids and ferns were all < 0.001) because there were evergreen plants in winter, such as *Vaccinium bracteatum*, *Citrus reticulata*, *Eurya japonica* and *Loropetalum chinensis*, which could provide food for the deer. Herbaceous plants decreased while woody plants increased from spring to winter. The diet was dominated by forbs in spring (48.39%) and summer (49.73%) and shifted to woody plants in autumn (58.97%) and winter (61.15%), but both of them were the main components of diet in all seasons (Fig. 2). Even though graminoids were increased from spring to winter, they were just a minority (0.81% - 6.83%) in the diet. Ferns were less selected by the water deer (6.45%,

2.41%, 7.69%, 12.95% from spring to winter), but with a trend of increase and more than graminoids in winter because some of them were still green then.

Even though there was no significance of diet composition by families among seasons (Kruskal-Wallis H test, $H = 3.21$, $df = 3$, $P = 0.2$), plant families were consumed variously in different seasons (Fig. 3).

The top ten plant families of diet composition consumed by the water deer in each season were different, and they all occupied more than 70% of total consumption in their seasons (Table 1).

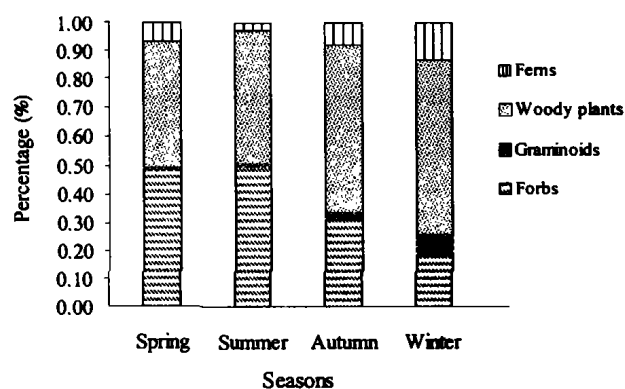


Fig. 2 Diet composition among seasons of the Chinese water deer in Zhoushan Archipelago

It showed that the water deer consumed much more of Leguminosae than other families in all seasons except winter when it was still the second most consumed plant (more than 30% in other three seasons but just 10% in winter). And their proportions in diet composition changed significantly among seasons ($\chi^2 = 15.54$, $df = 3$, $P = 0.001$). The woody plant *Quercus fabri*, which belongs to Fagaceae was selected more in spring and summer. Ericaceae was also selected more especially in winter when it was predominantly eaten. The proportion of Gramineae and Rutaceae in the feces progressively increased from a minimum level of 0.79% and 0.26% in the spring to 2.14% and 2.56% in the autumn, but all of them suddenly increased to 6.83% in the winter. Rosaceae was selected much constantly in all seasons (Chi-Square Test, $\chi^2 = 1.52$, $P = 0.68$), also Compositae and Hamamelidaceae were eaten with no significant differences among seasons (Chi-Square Test, $\chi^2 = 2.44$ and 3.14 , $P = 0.49$ and 0.37).

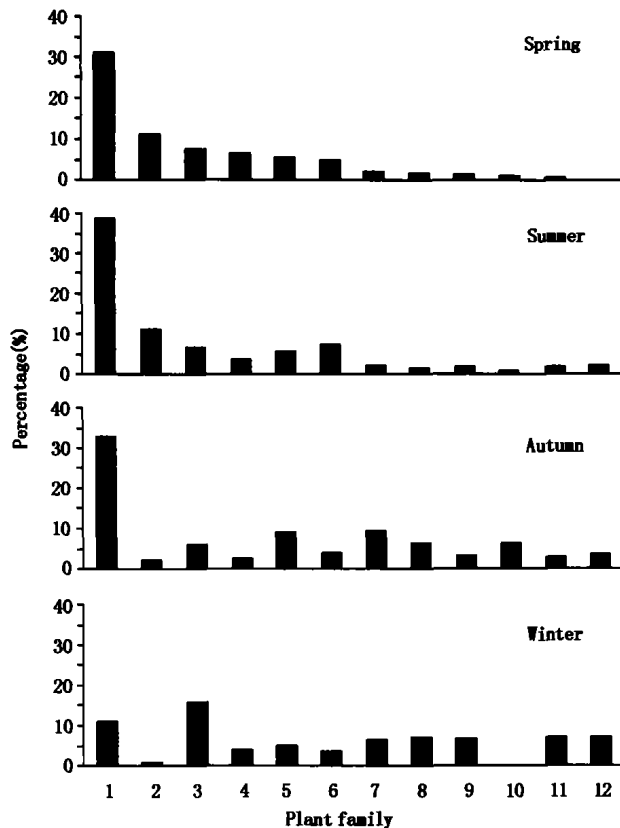


Fig.3 The proportion of some plant families in the diet of the Chinese water deer in different seasons*

*: The top 5 families of each season (top 6 families in winter were used because the 5th and the 6th family had same number of species) were compiled and 12 families were generated, and they were re-ordered by their percentage in spring. These 12 families are: Leguminosae, Fagaceae, Ericaceae, Hamamelidaceae, Rosaceae, Compositae, Apocynaceae, Thelypteridaceae, Myrsinaceae, Ulmaceae, Gramineae and Rutaceae by the sequence of number 1 - 12 showed in the above figure

4.3 Result of feeding trials

These 39 species were all taken more or less. The seriously bitten ones were *Ipomoea batatas*, *Rosa cymosa*, *Ulmus parvifolia*, *Patrinia scabiosaeifolia*, *Myrica rubra*, and *Trachelospermum jasminoides* and much was eaten. Also *Phyllostachys heterocyclus*, *Ilex kwangtungensis* and *Camellia oleifera* were bitten and eaten some. But *Cunninghamia lanceolata*, *Melia azadarach* and *Phytolacca americana* were bitten little and none was eaten perhaps because of the bad smell and taste. Only the tender top parts of the woody plants were bitten.

Water deer prefer leaves to stems, especially for woody plants, the same as the above result of observation traces in the wild. The stems of herbage were bitten much more than those of woody plants and ferns. The deer ate 10 plant fruits except that of *Phytolacca americana*. It was strange that almost all the odoriferous fruits of *Paederia scandens* were eaten and the deer also ate *Houttuynia cordata*, which had a bad smell too.

5 Discussion

5.1 The Chinese water deer is a concentrate feeder or a browser.

In conclusion, the Chinese water deer fed on at least 137 plant species, included in 61 families and 115 genera by summing up the above three methods and the proportion of the four plant types were forbs 59.12%, graminoids 2.92%, woody plants 31.39% and ferns 6.57%.

Table 1 The top ten plant families of diet composition among the seasons

Spring		Summer		Autumn		Winter	
Family	Percentage (%)	Family	Percentage (%)	Family	Percentage (%)	Family	Percentage (%)
Leguminosae	31.23	Leguminosae	38.24	Leguminosae	32.48	Ericaceae	15.83
Fagaceae	11.02	Fagaceae	10.43	Rosaceae	8.55	Leguminosae	10.79
Ericaceae	7.35	Pteridiaceae	6.68	Apocynaceae	8.55	Gramineae	6.83
Hamamelidaceae	6.3	Ericaceae	5.88	Thelypteridaceae	5.56	Rutaceae	6.83
Rosaceae	5.51	Rosaceae	5.08	Ulmaceae	5.56	Thelypteridaceae	6.47
Compositae	4.72	Moraceae	3.48	Ericaceae	5.13	Myrsinaceae	6.47
Urticaceae	4.72	Urticaceae	3.21	Urticaceae	5.13	Apocynaceae	6.12
Pteridiaceae	3.67	Vitaceae	2.94	Pteridiaceae	2.99	Elaeagnaceae	5.4
Moraceae	2.1	Hamamelidaceae	2.67	Rubiaceae	2.56	Pteridiaceae	5.04
Labiatae	1.84	Labiatae	2.14	Rutaceae	2.56	Rosaceae	4.68
Sum	78.46	Sum	80.75	Sum	79.07	Sum	74.46

The results indicated that Chinese water deer is a concentrate feeder or a browser in Zhoushan Archipelago, because most components (90.51% by synthesized results

and 89.91% by average of fecal analysis) of its diet were woody plants and forbs while grasses were a small part. It is consistent with Hofmann *et al.* (1988), Cook and Far-

rell (1998) and Hudson and White (1985), but not with Key *et al.* (1980) and Zhang (2000).

5.2 Grazer or browser, it depends?

How can we judge the feeding type of deer? Perhaps certain animals would be judged as different feeding types in different vegetation environments, or by different methods, such as stomach anatomy or food habit analysis. The Chinese water deer is just such an example (see the above introduction). In Zhoushan, there were rich plant species and vegetation types with 39.34% of forest coverage, and a certain number of them were evergreen ones, such as some species of Ericaceae, Gramineae, Apocynaceae, Hamamelidaceae, Fagaceae, Rosaceae, Rutaceae and Ferns, which could provide relatively enough food for the water deer in all seasons, even though perhaps there was less nutrition in the food in winter. And the water deer selected graminoids much less in every season even though the Gramineae had the most genera relative to other families. The water deer behaved more like a browser than a grazer for its main foods were woody plants and forbs other than graminoids. Another study conducted in Zhoushan also showed that the water deer selected predominantly herbs and brush-grasses (Wang and Sheng, 1990). Diet studies of the deer in its natural habitat in Yancheng Nature Reserve, China, where almost all the vegetation consists of *Imperata cylindrica*, *Aeluropus littoralis*, *Suaeda yhuaura*, *Suaeda salsa* and *Spartina angelica* communities and a few shrubs, supported that the deer was a intermediate or mixed feeder but tended to be a browser as the data showed that 87.3% of the diets were forbs and grass species and the rest were woody plants. And it was also found that of a total of 48 species of forbs and grass that the deer ate, only 15% species were grasses (personal observation) even though the water deer preferred the habitats that were covered mainly with the graminoid plants, such as *Imperata cylindrical* and *Aeluropus littoralis* (Wu, 2001). However, in Poyang Lake Nature Reserve where the vast grassland occupied 87.7% of the area while forest just 1.3%, the main plant were *Vitex trifolia var. unifolialata*, *Artemisia capollawis*, *Lespedeza Formosa*, *Eremo-chloa ophiuroides* and *Kummerowia stipulaceae* (Wang and Wan, 2000), and the main foods of the water deer were *Kaimenis*, *Viola*, *Poly-*

gonum, *Artemisia*, *Centella*, *Potentilla* and some aquatic plant species (Sheng, 1992). So, it may be at least an intermediate feeder and perhaps tended to be a browser too like that in Yancheng. The studies in Whipsnade Wild Animal Park in England also showed that water deer fed mainly on grasses (54%) and then on forbs (37%), because 27.2% of plants were graminoids while woody plants were only 17.1% in the park (Zhang, 1996, 2000). This might be due to the lack of natural or diverse vegetation types in their preferred location within the environment of the park (Hofmann *et al.*, 1988; Cook and Farrell, 1998). So the water deer there could be considered as a grazer, but it should not be regarded as mainly a grazer although it feeds only on grass (Zhang, 2000). The personal observations also showed that it did not feed like sheep or cattle and attempt to select from the sward (Hofmann *et al.*, 1988). And it has also been classified by Cook and Farrell (1998) on the basis of gut anatomy as being a concentrate selector but the studies on its food do not completely support this supposition as grasses and similar species contribute a considerable proportion of its diet. However, according to the comparative studies of the digestive system of bovids and cervids (Hofmann, 1973, 1985), the water deer had been grouped, based on numerous morphological criteria of their digestive system, into the group of concentrate selectors approaching an intermediate position. And the evidence in the morphophysiological adaptation of their digestive organs also suggested that it was primarily selecting for plant cell contents and easily digestible plant material in the grass and forbs layer and the lower strata of shrubs and herbs (Hofmann *et al.*, 1988). From a view of history, the water deer has been forced by human activities to move from the forest to wetland grassland near the Yangtze River shores and coastal habitats in China (Ohtaishi, 1992), so they might be undergoing a change in diet and foraging from woody plants-forbs in forest to forbs-grasses in grassland (Zhang, 1996, 2000). As Hofmann (1989) said that individual ruminant species gradually adapted to usage of different compounds of food supply, and forage selectivity is considered to be the key to their adaptability to different environmental conditions. So the Chinese water deer should be a browser or a concentrate feeder, but it could

select food only according to the availability of the environment. It also happened in other species, such as sika deer (*Cervus nippon*), which might be regarded as a grazer in Mt. Goyo, northern Japan, because the graminoids occupied 52.52% (the average of four seasons) of its diet (Takatsuki and Ikeda, 1993); but it might also be considered as a browser in Sichuan, China, because the majority of its foods were leaves of woody plants and forbs with a small part of grasses (Guo, 2001). In some environments, especially in poor vegetation circumstances, perhaps the diet composition could not truly reflect the real food types of the herbivores. And the water deer in Zhoushan was the largest and heaviest of all the four populations (Zhoushan population, Yancheng population, Poyang Lake population and Whipsnade population) (personal correspondence), not to mention that it was undernourished in Whipsnade because of the poor vegetation (Hofmann *et al.*, 1988).

How can we know what exactly the food type a herbivore is? Generally, herbivores feed to a certain extent according to their gene types, physical status, feeding habits and environment resources. In some species, seasonal changes may be the main factor for their diets (Hudson and White, 1985). Usually there is less food in winter, especially in the northern places where it is crucial for animals to find enough food or gain enough nutrition from the food. Diet compositions of deer are also different among seasons, especially in winter when they are obviously different from that in other seasons, such as red deer (*Cervus elaphus*) (Chen *et al.*, 1998), white-tailed deer (*Odocoileus virginianus*) (Christopher and Robert, 1983; Ramirez *et al.*, 1996), sika deer (Takatsuki and Ikeda, 1993), and other herbivores such as Prezwalski's gazelle (*Procapra przewalskii*) (Li *et al.*, 1999), and Himalayan musk deer (*Moschus chrysogaster*) (Green, 1987). We suppose that the results of stomach anatomy are relatively believable because the structure of each system determines its particular function (Miller and Harley, 1994).

5.3 Comparison with other Chinese water deer populations

We have compared the diet compositions of the Chinese water deer from different populations in 1996 (Zhang, unpublished data), they behaved differently in

diet but not significantly among the three populations. But there was a high difference among the three plant types by species, while the proportions in the diet compositions were also highly significant in graminoids and woody plants but not significantly different in forbs among the three populations. The trial of rumen contents at Whipsnade in spring of 1994 revealed that 71% of plant fragments were grasses, sedges and rushes, 24% were herbs and 4% were woody plants (Cook and Farrell, 1998). While the results of MAF in the same season in Zhoushan showed that 48.39% were forbs, 44.35% were woody plants, 6.45% were ferns, but only 0.81% was graminoids. Such large differences were also met in musk deer of different populations (Green, 1987). But in Zhoushan there were many more woody plants than in Whipsnade and Yancheng, and forbs were also rich in species and distributions. So the water deer selected more woody plants but fewer graminoids in Zhoushan than in the other two places. However, graminoids occupied a large proportion in the diet of composition in other two populations perhaps because that there was lack of other plants. The primary study of diet of the water deer in Poyang Lake National Reserve, China where the vegetation types were dominated by herbaceous plants, also showed forbs were its main food.

6 Conclusion

There was a complex component in the diet of the Chinese water deer in Zhoushan Archipelago, and it should be a concentrate feeder or a browser according to the study conducted with methods of observing feeding signs in the wild, microhistological analysis of feces and feeding trials.

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References:

- Chen H, Ma J, Li F, Sun Zh, Wang H, Luo L, Li F. 1998. Seasonal com-

- position and quality of red deer *Cervus elaphus* diets in northeastern China. *Acta Theriologica*, 43(1): 77–94.
- Christopher W, Robert B. 1983. Feed intake and digestive efficiency of south Texas white-tailed deer. *Journal of Wildlife Management*, 47(2): 442–450.
- Cook A, Farrell L. 1998. Chinese Water Deer. The Mammal Society and The British Deer Society, London, England.
- Gordon I J, Illius A W. 1988. Incisor arcade structure and diet selection in ruminants. *Functional Ecology*, 2: 15–22.
- Green M J B. 1987. Diet composition and quality in Himalayan musk deer based on fecal analysis. *Journal of Wildlife Management*, 51(4): 880–892.
- Guo G, Zhang E. 2002. The distribution of the Chinese water deer (*Hydropotes inermis*) in Zhoushan Archipelago, Zhejiang Province, China. *Acta Theriologica Sinica*, 22(2): 98–107.
- Guo Y S. 2001. Study on the food habits of Sichuan sika deer (*Cervus nippon-sichuanicus*). *Journal of Sichuan Teachers College (Nature Science)*, 22(2): 111–119. (in Chinese with English abstract)
- Hofmann R R. 1973. The ruminant stomach: stomach structure and feeding habits of East African game ruminants (East African Monographs in Biology, vol. 2.). East African Literature Bureau, Nairobi, Kenya.
- Hofmann R R. 1985. Digestive physiology of the deer their morphophysiological specialization and adaptation. In: Fennessy P F, Drew K R eds. The Royal Society of New Zealand Bulletin: Biology of Deer Production. Wellington, New Zealand. 22: 393–407.
- Hofmann R R, Kock R A, Ludwig J. 1988. Seasonal changes in rumen papillary development and body condition in free ranging Chinese water deer (*Hydropotes inermis*). *J Zool Lond*, 216: 103–107.
- Hofmann R R. 1989. Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia*, 78: 443–457.
- Hudson R J. 1985. Body size, energetics, and adaptive radiation. In: Hudson R J, White R G eds. Bioenergetics of Wild Herbivores. CRC Press, Inc., Florida, USA. 1–24.
- Hudson R J, White R G. 1985. Bioenergetics of Wild Herbivores. CRC Press, Florida, USA.
- Insular Vegetation Resources Investigating Group of Zhoushan Forest Bureau. 1999. Investigation report on insular vegetation resources of Zhoushan Area, Zhejiang Province. Zhoushan Forest Bureau, Zhejiang Province, China. (in Chinese)
- Jarman P J. 1971. Diets of large mammals in the woodlands around lake Kariba, Rhodesia. *Oecologia*, 8: 157–178.
- Jarman P J, Sinclair A R E. 1979. Feeding strategies and the pattern of resource partitioning in ungulates. In: Sinclair A R E, Norton-Griffiths M eds. Serengeti: Dynamics of An Ecosystem. University of Chicago Press, USA. 130–163.
- Jin P, Chen X, Zhang X, Li G, Zhang R. 1991. Research on the regional botanical system in Zhoushan Islands. *Jour of Zhejiang Forestry Sci & Tech*, 11(3): 1–30.
- Key R N B, Engelhardt W V, White R G. 1980. The digestive physiology of wild ruminants. In: Ruckebusch Y, Thivend P eds. Digestive physiology, and metabolism in ruminants. MTP Press, Lancaster, U. K. 743–761.
- Litvaitis J A, Titus K, Anderson E M. 1996. Measuring vertebrate use of terrestrial habitats and foods. In: Bookhout T A ed. Research and Management Techniques for Wildlife and Habitats. Fifth ed. rev. The Wildlife Society, Bethesda, USA. 254–274.
- Li D, Jiang Zh, Wang Z. 1999. Diet analysis of *Procapra przewalskii*. *Zoological Research Sinica*, 20(1): 74–77. (in Chinese with English abstract)
- Miller S A, Harley J P. 1994. Zoology, 2nd edn. Wm. C. Brown Publishers, Dubuque, USA. 506.
- Ohtaishi N. 1992. The origins and evolution of the deer in China. In: Sheng H ed. The Deer in China. Shanghai: East China Normal University Press, 8–18.
- Remirez R G, Haenlein G F W, Treviño A, Reyna J. 1996. Nutrient and mineral profile of white-tailed deer (*Odocoileus virginianus texanus*) diet in northeastern Mexico. *Small Ruminant Research*, 23: 7–16.
- Sheng H. 1992. The Deer in China. (in Chinese with English summaries). Shanghai: East China Normal University Press, 96–115.
- Sun Li, Sheng H. 1990. Chinese water deer at the areas of Poyang Lake. *Journal of East China Normal University (Mamm. Ecol. Suppl.)*, 21–26.
- Storr G M. 1961. Microscopic analysis of faeces, a technique for ascertaining the diet of herbivorous mammals. *Australian Journal of Biological Science*, 14(1): 157–164.
- Takatsuki S, Ikeda S. 1993. Botanical and chemical composition of rumen contents of Sika deer on Mt. Goyo, northern Japan. *Ecological Research*, 8: 57–64.
- Van Soest P J. 1980. The limitations of ruminants. Proc. Cornell Nutr. Conf. 78–90.
- Van Soest P J. 1982. Nutritional ecology of the ruminant. O and A Books, Corwalis, USA. 374.
- Wang H, Sheng H. 1990. Population density and habitat selection of Chinese water deer in Zhoushan Islands. *J East China Normal University (Mamm. Ecol. Suppl.)*: 43–46. (in Chinese with English abstract)
- Wu Y. 2001. Habitat Use and Selection by Chinese Water Deer in Yancheng Biosphere Reserve, China. (M. D. dissertation). East China Normal University, Shanghai, China. (in Chinese with English abstract)
- Wang J, Wan H. 2000. The conservation and sustainable utilization for biodiversity of Poyang Lake wet land vegetation. *Environment and Exploiture*, 15(4): 19–21. (in Chinese with English abstract)
- Xu L. 1981. Chinese precious *Hydropotes inermis*. *Acta Theriologica Sinica*, 1(2): 135–136.
- Zhang E. 2000. Ingestive behavior of the Chinese water deer. *Zoological Research Sinica*, 21(1): 88–91.
- Zhang E, Guo G. 2000. Poaching as a major threat to Chinese water deer in Zhoushan Archipelago, Zhejiang Province, P R China. *Deer*, 11(8): 413–414.
- Zhang E. 1996. Behavioral Ecology of Chinese Water Deer at Whipsnade Wild Animal Park, England. (Ph. D. dissertation). Cambridge University, Cambridge, England.