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Food composition and feeding ecology of the Red Fox *Vulpes vulpes* (Linnaeus, 1758) in Egypt

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ABSTRACT

Food composition of the Red Fox *Vulpes vulpes* populations in different habitats in Egypt is investigated based on the analysis of stomach contents. The analysis of 70 stomach contents demonstrates that the food of Red Fox is highly diverse and includes rodents, birds, reptiles, fishes, insects and other arthropods, fruits and other vegetable material. Certain individuals seem to also feed on carrion. Diet composition shows seasonal and geographical variations that are apparently associated with changes in the availability of different food items. The results clearly show that the Red Fox is an opportunistic omnivore, capable of adapting to a great variety of dietary compositions.

KEYWORDS: Red Fox, *Vulpes vulpes*, food, Egypt.

INTRODUCTION

The Red Fox *Vulpes vulpes* is the most widely distributed carnivore in the world and the most abundant carnivore in Egypt. It is one of the most adaptable mammals, being able to survive in a variety of habitats ranging from the arctic areas, to the barren temperate deserts, and the densely populated cities. Its extreme adaptability makes it particularly difficult to draw general conclusions regarding many aspects of biology, the parameters of which tend to vary locally. The outstanding adaptability of this carnivore is clearly manifested in its ability to feed on a great variety of food items, which allows it to survive in a great variety of environmental settings. Being the key predator in many of the Egyptian habitats (Osborn & Helmy, 1980) it plays an ecological role of special importance. As such, a thorough knowledge of its food and feeding habits in different habitats and seasons is necessary for our understanding of the ecology of many of these habitats as well the pattern of distribution of this canid among available habitats (Macdonald, 1983). However, available information on food and feeding habits of the Red Fox and other wild carnivores in Egypt is very limited in the literature (Osborn & Helmy, 1980; Basuony, 1998). In this study, we examine in detail the feeding ecology of the Red Fox in different types of habitats in Egypt and investigate any possible seasonal fluctuations in diet composition. The investigation is based upon examining a large collection of stomach contents of this species, which allowed a relatively thorough assessment and comparison of the breadth of trophic niche for the fox populations in the Nile Valley and different desert areas.

MATERIALS AND METHODS

The diet of the Red Fox was investigated by the exhaustive analysis of the stomach contents of 70 adult specimens. Most of the foxes were captured in steel traps by commercial fur trappers. The animal was killed shortly after capture and a scientist accompanying the trappers immediately removed the stomach and preserved its contents in 10% formalin for subsequent laboratory analysis. Since commercial trapping generally occurred only in autumn and winter, some animals were trapped during spring and summer for the sake of completing a full annual

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cycle. Samples were obtained from the Mediterranean coastal desert, mostly in the vicinity of El Dabaa, different parts of the Nile Delta, Nile Valley, oases of the Western Desert and *khors* of Lake Nasser. Figure 1 shows the collection localities of material covered in this paper.

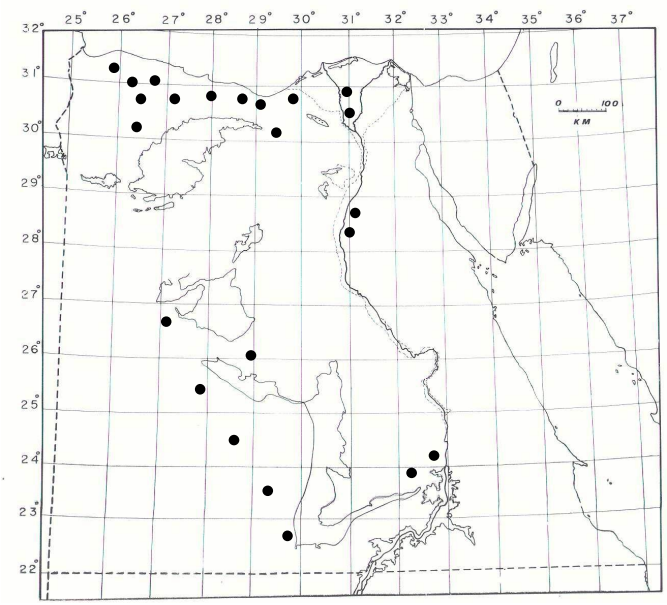

Figure 1: Collection localities of the Red Fox *Vulpes vulpes* from Egypt.

At the laboratory, the stomach contents were weighed, examined and categorized into main items. The identification of plant fragments in the stomach contents was based on the comparison of plant epidermal remains with a reference collection prepared from plants present at the different study areas. The reference slides were prepared using Storr's method (1961).

The identification of the animal items in the food was carried out to the smallest possible taxonomic category. Identification to species level was possible if the item was represented by the entire animal or fragments representing characteristic morphologic feature of the species. Reptiles were identified on the basis of scale morphology and/or toe structures. Birds were identified based on skull morphology and feathers. The mammals consumed could sometimes be established from bones, almost always from teeth, when present, hair morphology and often from whole feet or tails. Insects were mostly identified to the order level. The frequency of occurrence of animal and plant food items was calculated according to the method developed by Sparks & Malechek (1968).

Trophic niche breadth was calculated according to the method described by Levins (1968) and Ricklefs (1980), and the index applied to the frequency and volume of the various food categories. The Levin's Index formula is:

$$\mathbf{B} = \Sigma\ 1/\ \mathbf{p}^2_i$$

Where $\mathbf{p_i}$ is the proportion of records in each food category **i**. The trophic niche breadth value was calculated seasonally.

RESULTS

Western Mediterranean Coastal Desert

Thirty stomachs were examined, three of which were found to be empty as the time of capture of these animals coincided with the beginning of the fox's activity period. Table 1 shows the general composition of the diet, expressed as the number of stomachs containing the item and

frequency of occurrences of detected item in stomach samples (expressed as a percentage of all samples) of all individual food items encountered in the remaining thirty stomach contents.

The table shows that although the diet shows considerable variability among individuals, mammals constitute the predominant item in half of the analyzed stomach contents. Of mammalian remains detected in the samples, two wild species of the Mediterranean coastal desert habitat, namely the Cape Hare *Lepus capensis* and the Fat Sand Rat *Psammomys obesus,* and two commensal species, the Brown Rat *Rattus rattus* and the house mouse *Mus musculus* are best represented. Hair and skin of domestic goats often appeared in most of the stomach contents analyzed, possibly indication feeding on carrion although depredation on small goats cannot be totally ruled out. The hare *Lepus capensis*, which is very abundant in the coastal areas of the Mediterranean, appeared in six stomach contents and may actually form the preferred mammalian prey species in the fox diet.

Insects form the second most important food item in the contents of the stomachs of foxes from that area. One third of the analyzed stomach contents had insect remains. It is interesting that the household American Cockroach *Periplaneta americana* frequently appeared in the stomach contents of the foxes, indicating that they forage close to human habitations where this insect can be usually found. Beetles, locusts and mantids are among the more frequently found insects in stomach contents (Table 1). It is worth nothing that a great variety of items that can be collectively called human garbage appear in the stomachs of these foxes, possibly indication that garbage dump sites may form important foraging area for these animals.

Reptiles and scorpions also occurred in the diet of the Red Fox at relatively high frequencies (19 %) being detected in five stomachs each. Reptiles were represented by several lizard species such as *Stenodactylus sthenodactylus*, *Trapelus mutabilis*, *Laudakia stellio* and *Chalcedis ocellatus* and the snake *Psammophis schokari*. Two scorpions *Buthus sp.* and *Androctonus* sp. were also detected in the fox's diet.. The presence of birds in the diet of the fox is infrequent. Remains of birds were detected in four stomachs and had a frequency of occurrence of 15 % in the examined sample. These remains were mostly domestic chicken and the domestic pigeon.

Plant remains also appeared in the stomach contents of some foxes. Some of these seem to be accidentally ingested by the foxes while consuming other food items. Certain plants appear to be actively eaten by the foxes and their remains are found in some of the stomach contents. These include the leaves of both *Zea mays*, and *Acacia sp*. Fruits grown in the study area including *Phoenix dactylifera*, *Ficus carica*, *Arundo sp*., *Capsicum annum*, *Tomato sp*. and *Phoenix dactylifera*. occur in the stomach contents of the Red Fox and seem to be regularly taken (Table 1).

Table 1: Occurrence and frequency (expressed as a percentage) of food items in the stomach contents of the Red Fox *Vulpes vulpes* from the Western Mediterranean Coastal Desert.

Food item	Number of stomachs containing the item (N= 27)	Frequency of occurrence (%)
Vertebrates		
Mammals	13	48.15
Birds	4	14.81
Reptiles	5	18.52
Invertebrates		
Insects	9	33.33
Scorpions	5	18.52
Plant material (fruits)		
Tomato sp	1	3.7
Ficus carica	2	7.4

Capsicum annum	2	7.4
Arundo sp.	1	3.7
Phoenix sp.	4	14.81
Plant materials (leaves)		
Zea mays	1	3.7
Acacia sp.	1	3.7
Salix safsaf	2	7.4
Phragmites sp.	1	3.7
Unidentified plants	2	7.4
Assorted human refuse	4	14.81

Seasonal variation of diet

Table 2 shows a comparison of results of stomach content analysis from the Western Mediterranean Coastal Desert in four seasons over a period of 15 months. It is clear from the table that considerable changes in the occurrence of most food items take place. One exception was the frequency of occurrence of insects which did not change to any great extent during different seasons.

The estimation of niche breadth revealed that their values showed some seasonal changes. The value of the trophic niche breadth was at its maximum in summer and spring and at its minimum in the winter (Table 2). These changes seem to reflect the fluctuations in the diversity of available food items in the environment. It should be noted, however, that although the calculated value of the niche breadth remains more or less the same, the composition of the diet shows significant seasonal changes, which implies that certain items replace other as seasons change.

Table 2: Seasonal variation in Red Fox diet from the Western Mediterranean Coastal Desert, expressed as number of occurrence (NO) and frequency of occurrence (FO) of selected food items, and the calculated trophic niche breadth (NB).

Food item	Winter 01 N=9		Spring 01 N=8		Summer 01 N=4		Autumn 01 N=1		Winter 02 N=5	
	NO	FO	NO	FO	NO	FO	NO	FO	NO	FO
Mammals	5	55.6	4	50	3	75	1	100	-	-
Reptiles	2	22.2	4	50	-	-	1	100	1	20
Birds	2	22.2	-	-	-	-	-	-	1	20
Scorpions	1	11.1	4	50	-	-	-	-	-	-
Insects	3	33.3	2	25	1	25	1	100	2	40
Plants	7	77.8	-	-	1	25	1	100	4	80
Garbage	2	22.2	2	25	2	50	-	-	1	20
Dates	-	-	2	25	-	-	-	-	2	40
NB	-	0.84	-	1.07	-	1.07	-	1.0	-	0.93

Geographical Variation in Diet

Table 3 compares the results of stomach content analysis of fox populations from different parts of the country. The occurrence and frequency (expressed as a percentage) of each food item in the stomach contents of the animals from different geographical regions of Egypt were determined (Fig. 1). These regions represent the main habitat types occupied by this fox in Egypt.

Western Desert Oases

The inhabited Western-Desert oases of Bahariya, Farafra, Dakhla and Kharga were sampled. Palm dates occurred more frequently in the stomach contents of the oases foxes than any other food item. This seems to reflect the great abundance of these fruits in the oasis habitats. Dates were detected in nine of the fifteen stomachs examined (60%). Insects occurred only in three

stomachs (20% of the examined) and were mostly represented by coleopterans and orthopterans. Scorpions of genus *Buthus*, reptiles (*Mabuya quinquetaeniata*), birds (chicken and pigeons) and mammals (*Rattus rattus* and *Oryctolagus caniculus*) were found in the stomach contents in equal percentages (13.33%) (Table 3).

Lake Nasser
Remains of fish were frequently found in the stomach contents of foxes living around Lake Nasser (Table 3). The foxes were collected from areas where several fishermen operated, possibly indicating that foxes take fish caught by fishermen or fish remains discarded by them. Foxes may also catch fish in shallow areas near lake shore. Fish remains were found in the contents of the three stomachs examined. The spider (*Galeodes sp*.), scorpion (*Androctonus australis*) and the dermapteran insect (*Labidura riparia*) were also found in stomachs. Plant material was found in all stomachs analyzed. These represent tomatoes, potatoes, apparently used by fishermen and *Arundo sp*.

Nile Delta
Samples were obtained from the intensively cultivated, densely populated Al-Sharqiya Governorate in the Nile Delta. Stomach contents from 15 individuals captured from a rural area of the governorate were analyzed, one of which was found to be empty as the time of capture of these animals coincided with the beginning of the fox's activity period (Table 3). Remains of birds, especially domestic chickens, house sparrows *Passer domesticus* and domestic pigeons occurred in more stomachs than any other food items (78.6%). Mammals (*Mus musculus*, *Rattus sp*. and *Oryctolagus caniculus*) and plant remains come next, being found six stomachs (42.9%) each. Reptiles (*Psammophis sibilans*) and the insect *Gryllotalpa gryllotalpa* were also recorded.

Nile Valley
Stomach contents of seven foxes were obtained in Beni Suef Governorate, east of the Nile in a rural area typical of that part of the Nile Valley (Table 3). Remains of insects (*Gryllus bimaculatus*, *Gryllotalpa gryllotalpa* and caterpillar larvae) and fruits (*Xanthium brasilicum* and *Capsicum annum*) were the most abundant in the stomach contents occurring in six stomachs each (85.7%). Remains of reptiles (*Psammophis sibilans* and *Ramphotyphlops braminus*), birds (domestic chickens) and scorpions (*Buthus* sp. and *Androctonus* sp.) each occurred only in two stomachs. One stomach contains the remains of a bird egg.

Comparison of the trophic niche breadth in different geographical areas show major differences among fox populations in different areas (Table 3). These differences may be related to the different ecological conditions and hence composition of available food.

DISCUSSION

Based on our data and reports by others, the Red Fox is essentially an omnivore (Flower 1932; Macdonald 1979; Osborn & Helmy 1980). Its diet is extremely varied, and includes invertebrates (particularly beetles, mole crickets, earthworms and crabs), small mammals (rodents, lagomorphs and weasels), birds (including game species), fishes, fruits and carrion (Flower 1932; Macdonald 1979; Osborn & Helmy 1980).

Our data confirm the opportunistic foraging habits of the Red Fox *Vulpes vulpes* throughout its almost world-wide habitats as reported by many authors (e.g. Englund 1965; Amores 1975; Ciampaloni & Lovari 1985; Calisti *et al*. 1990) and in Egypt (Osborn & Helmy 1980; Basuony 1998). The data clearly show that this mammal will eat virtually whatever food is available locally. The type and quantity of available food source will obviously depend on the type of habitat and the season. For such a highly opportunistic species, different

proportions of plants, invertebrates and vertebrates found in diets in different areas should be correlated with the availability of these resources. Accordingly, one could expect that, as a "generalist", the fox will start eating numbers of insects and other arthropod in areas where these are abundant, as in regions with mild climate and rich plant covers, which favor the availability of insects (Blondel 1969). One could also predict that items rich in sugar such as dates will be favored as immediate sources of energy when caloric requirements are greatest. Obviously, vegetable food is everywhere important in the diet of the fox. Leaves of *Salix safsaf*, *Acacia raddiana*, *Zea mays* and *Phragmites australis*, that are often found in the diet, would not fall under this category of high energy foods. They may either be accidentally taken with other foods or are taken only when nothing else is available. Fruits if available especially that of high sugar contents such as dates and figs are ingested by the Red Fox inhabiting the oases of Western Desert and the Mediterranean coastal desert, where palm groves and fig gardens are abundant. Other fruit such as Tomato, *Capsicum annum* and *Arundo sp*. form important items in the food of the Red Fox. This confirms the same observations on the Red Fox in the Mediterranean area of south Europe (Ciampaloni & Lovari 1985; Calisti *et al*. 1990). Resources rich in proteins (mammals and birds) may be expected in the diet in the carnivore especially during pregnancy (Ciampaloni & Lovari 1985). Our results are consistent with such expectations.

Optimal foraging theory states that a predator should choose prey types based on trade-off between costs and benefits that will give the maximum net benefit to the individual (Krebs & Davis 1993). The dietary choices of small carnivores such as the Red Fox will depend primarily on the temporal variation of foraging costs (Erlinge 1981; Raymond *et al*. 1990; Zielinski 1988), which are mainly affected by availability of the primary prey species. Our data also show that rodents, the primary prey for the Red Fox, are always taken when available, suggesting that the costs of harvesting rodents, which are abundant throughout the year, are never high. Similarly the frequently found remains of domestic farm animals (chicken, rabbit, pigeon, and goat) show the fox's tendency to select easy-to-catch prey species that require the expenditure of minimal energy. Similarly, feeding on carrion would be most cost effective. The consumption of alternative prey is independent of its availability, and increases only when relative benefits of harvesting alternative food (e.g. fruits) increases, which is consistent with optimal foraging theory (Martinoli *et al*. 2001).

Seasonal and geographical variation in the diet composition of the Red Fox relate to the seasonal and geographical variation in available food. The observed high degree of variability diet composition also reflects the ability of this animal to adapt to highly variable dietary conditions. Furthermore, successful survival and expansion of the Red Fox in the anthropogenic landscapes of the Nile Delta and Valley, as well as the Western Desert Oases, is understandable by the fox's adaptation to opportunistic utilization of different, unstable prey in these heterogeneous habitats.

Comparison of the trophic niche breadth in different geographical areas shows some striking results. Animals living in ecologically impoverished areas, such as the arid shores of Lake Nasser had a very narrow trophic niche reflecting the meagre resources of this area. Alternatively, the fact that these animals feed almost exclusively on fish may actually reflect their tendency to exploit a particularly abundant food resource in the area. Similarly a narrow trophic niche was also observed in animals from the Nile Valley near Beni Suef. In this area, the narrow, cultivated flood plain of the river provide a relatively harsh, low diversity environment, which allows the fox only a limited opportunity for food selection.

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الملخص العربى

الغـذاء وايكولوجيا الأغتذاء فى الثعلب الأحمر *فولبس فولبس* (لينيوس، 1758) فى مصر.

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أجريت الدراسة على عشيرة الثعلب الأحمر فى مواطن كثيرة ذات صفات جغرافية مختلفة، فقد تم تجميع العينـات مـن الصحراء الغربية (الصحراء الساحلية والواحات) وذلك على مدار عام كامل، وادى النيل والدلتا ومنطقة بحيـرة ناصـر (الناحية الغربية). وبعد حفظ العينات التى تم صيدها (70 عينة) من بيئاتها الطبيعية، تم فحص محتوى المعـدة للوقـوف على مكونات الغذاء لأفراد الثعلب الأحمر موضوع البحث. أظهرت تحاليل المحتوى المعدى أن الغذاء فى الثعلب الأحمر عالى التنوع لأنه يتغذى على القوارض، الطيور، الزواحف، الأسماك، الحشرات والنباتات، كما يبدو أن بعـض الأفـراد تتغذى على الجيفة. كما بينت الدراسة أن هناك اختلاف جغرافى وموسمى فى المكونات الغذائية للثعلب الأحمـر وذلـك ارتباطاً بالتغيرات التى تحدث فى مختلف العناصر الغذائية المتاحة. وأوضحت الدراسة جلياً أن الثعلب الأحمـر متنـوع الغذاء يملك القدرة على التكيف بدرجة كبيرة فى تناول غذاء أخر عندما تنضب مصادر غذاؤه الأساسية.