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Vertebrate Pest Conference Proceedings collection

February 1994

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ABSTRACT: Introduced red fox in urban Orange County, California ate a wide variety of foods. Mammals and birds were consumed at all times of the year and both taxa appeared in approximately half or more of the fecal samples at all times of the year. Human supplied food remains were also common and supplemental feeding occurred at all study sites. Supplemental feeding has the potential to exacerbate problems for management of introduced red fox and several endangered species.

Proc. 16th Vertebr. PestConf. (W.S. Halverson& A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 1994.

INTRODUCTION

Red foxes *(Vulpes vulpes)* in California are only native to the Sierra Nevada mountains (Grinnell 1937). They were first introduced into other areas of California in the 1890s. Some introductions continue to the present time (Lewis et al. 1993). Introductions into these other parts of California are believed to have resulted from human activities (such as fur farming or sport). The known imports were from outside the state. The establishment of non-native foxes at sites where they had not previously existed resulted in serious wildlife concerns (U.S. Fish and Wildlife and U.S. Navy 1990, U.S. Fish and Wildlife 1990). Introduced red fox have been implicated in the declines of endangered species such as the least tern *(Sterna antillarum browni),* California clapper rail *(Rallus longirostris obsoleus),* light footed clapper rail (/?. *I. levipes),* Belding's savannah sparrow *(Passerculus sandwichensis beldingi)* and for conflicts with the San Joaquin kit fox *(Vulpes macrotis mutica)* (Rails et al. 1990). In urban Orange County these problems are extreme because the few remaining wetlands are restricted in size and surrounded by urban development.

In 1991 we began a study of food habits of red fox in urban Orange County, California. Red fox in England were reported to consume a wide variety of food types including natural prey and garbage, as well as domestic cats (Harris 1981, Macdonald 1987, Doncaster et al. 1990). Specifically, we identified the variety of food types and the regularity with which certain food types were included in the diet of the urban Orange County red foxes. Of special concern was the consumption of birds and the potential impact on endangered species.

METHODS

Fecal deposits (scat) of red fox were collected at seven locations in Orange County, California from June 12, 1990 to March 22, 1991 (approximately 3000 scats). Collection locations were comprised of urban and industrial development, residential areas, and open space (defined for this study as golf courses, parks, airfields, agricultural fields, wetlands, and undeveloped land). One of our collection locations was at Mile Square Park in Fountain Valley, California and was the site of concurrent red fox population estimates (Yaeger and Golightly 1993). Mile Square Park (2.25 km^2) was an abandoned airfield surrounded by parks and private golf courses.

We identified specific sites for scat collection at each of the seven locations. An initial collection, which was not used in data analysis, was obtained at each site to ensure the known age of ensuing fecal deposition. A monthly collection was subsequently collected from each site. Scats were air dried, labeled, stored in plastic food bags, and shipped to Humboldt State University, Department of Wildlife (HSU). Scats were frozen (Korschgen 1980) at HSU until analysis.

Collections of scat were examined by order of collection date. Randomly chosen samples weighing between 11 to 13 grams were selected from each collection site and month. Individual samples of dried scat were placed in nylon knee-hi stockings and soaked overnight in a dilute solution of bleach (5 ml of bleach/ 3 L of water). The stockings containing scat were agitated for ten minutes in a clothes-washing machine to further separate compacted fecal material (Johnson and Hansen 1977). The contents of washed nylons were emptied into 12 cm diameter aluminum pans and oven dried at 70' C overnight. Dried samples were stored in a desiccator while awaiting analysis.

For each sample, large undigested items were initially removed from the washed and dried scat and separated into categorical piles. The remaining material was systematically searched for a maximum of two hours under a dissecting microscope to identify and remove any minute but identifiable items (Southern and Watson 1941). Sorted remains were stored in glass vials. Additional samples were examined from each collection until no new items were found for that sample (Hanson and Graybill 1956).

Items removed from the scat were identified using reference texts (Borror 1970, Chu 1949, Comstock 1971, Hall 1959, Ingles 1965, Jameson 1988, Martin 1961, Montgomery 1977, Pohl 1954), identification keys (Day 1966, Hickman 1993, Mayer 1952, Moor 1974), the reference collections of the HSU vertebrate and wildlife museums and our own collection of skeletons, hair, feather, insect and seed collected specifically for this project. Mammals were identified by the presence of hair, bones, and teeth. Birds were identified by the presence of feathers and bones. Egg shell present in the scat was designated as a separate category and not specifically categorized as bird. Insects were identified by undigested exoskeleton. Vegetation was identified by the presence of seed. Crustaceans and mollusks were identified by exoskeleton and shell, respectively. Reptiles were identified by the presence of teeth and bone. Human food packaging items were also identified, as necessary. All biotic items found in the scat were identified to species if possible.

Each sample was categorized as an item being present or absent. The frequency of occurrence for each sample was calculated as the number of samples containing the item divided by the total number of samples examined.

At Mile Square Park, the amount of food provided to red foxes by one person was measured for 49 days. The weight of the food provided on each day C± 0.1 kg) and the type of food (beef, chicken, turkey, pork, unidentified fat, or fish) were recorded. Bread was also provided to the foxes by this individual but was not measured.

RESULTS

We examined 449 samples of scat and found a wide variety of food items (Table 1). Mammals were found at consistently high frequencies of occurrence in all seasons. Gophers (Family Geomyidae) were the most frequently identified item in all seasons and their frequency of occurrence was greatest in fall and winter. California Ground Squirrel *(Spermophilus beecheyi)* was more common in spring (Figure 1) than in other seasons. Opossum *(Didelphis virginianus),* domestic cat, shrew (Family Soricidae), deer mice *(Peromyscus* spp.), and lagomorphs were all identified in the scat, but never at a frequency of occurrence greater than 10%.

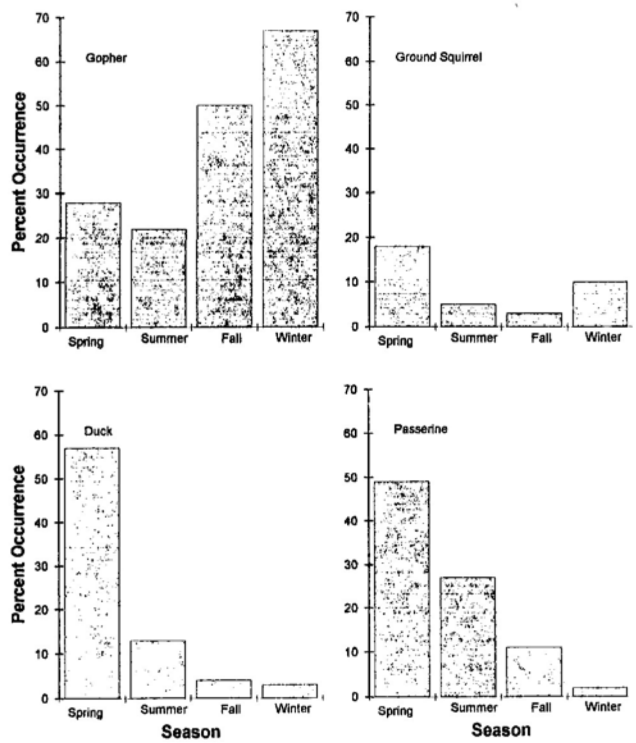
Birds were also consumed throughout the year with the greatest frequency in winter and spring (Table 1). Ducks (Family Anatidae) and song birds (Order Passeriformes) were found throughout the year, but most frequently in the spring (Figure 1). Falcons (Order Falconiformes) and starlings *(Sturnus vulgaris)* were found at frequencies of 15% and 10%, respectively, in spring and were absent or poorly represented in the scat at other times of the year. Owls (Family Strigidae), pigeons *(Columba livid),* domestic chicken (distinguished from store-bought chicken by the presence of feathers), and quail (Family Galliformes) were found at frequencies of occurrences less than 10%. Egg shells occurred most frequently in the spring samples.

Invertebrates were in almost all samples (including insects, arachnids, crustaceans, and mollusks). Reptiles were rarely present in the scat. Seeds (probably the result of fruit consumption) were also found throughout the year (more than 28 families). Materials associated with humans were consistent throughout the year and included such items as foil, plastic wrap, bologna and salami skins, candy wrappers, paper, and gum.

Both birds and mammals were found at den entrances and cache sites (Table 2). Positive identification to species or family was consistently possible with these items because of their relatively large size. The list of mammals was consistent with the scat results. The bird remains added new species to the list identified from scat.

At Mile Square Park, we acquired feeding data for 49 days. The single feeder provided 7.1 +_ 0.03 kg (x ± SE) of chicken parts, beef, and pork daily. Assuming 46 foxes at Mile Square Park (Yaeger and Golightly 1993), this was the equivalent of 0.15 kg/fox-day.

Figure 1. The percent occurrence (samples containing a food item divided by the total number of samples) of vertebrate food items by season which occurred in more than 10% of the



samples of red fox fecal droppings. Other vertebrate species were either unidentified or detected at frequencies less than 10%. Samples were collected from June 1990 to March 1991 in urban Orange County, California.

DISCUSSION

Red fox in urban southern California consumed a wide range of foods. In spite of their urban setting, natural prey (birds, bird eggs, mammals, and invertebrates) were consistently found to be part of the diet. Prey size varied from cormorants, ducks, gulls, domestic cats, and opossums to small song birds and insects. It might be argued that larger food items may have been salvaged from preexisting carcasses (e.g., dead on the highway); however, because of the consistent and relatively high frequency of occurrence of these items (e.g., ducks) it would be unlikely that they were gathered by scavenging alone.

Table 1. Percent occurrence of major food categories for fecal samples collected of introduced red fox in Orange County, California from June 1990 to March 1991.

Category (n)	Spring (67)	Summer (153)	Fall (169)	Winter (60)
Mammal	84	78	81	95
Bird	76	44	49	77
Egg Shell	13	4	3	0
Reptile	1	1	<1	0
Invertebrate	100	99	87	88
Container/other[a]	55	62	53	52
Seed	87	82	64	87

[a]Includes food items associated with humans such as foil, wrappers, styrofoam, gum, plastic, etc.

Table 2. Food items found in caches or at den entrances of introduced red fox in Orange and Los Angeles Counties, California from June 1990 to March 1991.

Common Name	Scientific Name
Ground Squirrel	*Spermophilus beechyei*
Cottontail	*Sylvilagus audubonii*
Domestic Rabbit	*Oryctolagus cuniculus*
Domestic cat	*Felis catus*
Opossum	*Diadelphis virginiana*
Gopher	*Thomomys bottae*
Gulls	*Larus* spp.
Ducks	*Anas* spp.
Domestic chickens	*Gallus domestica*
Pigeons	*Columba liva*
Godwit	*Limnosa* spp.
English sparrow	*Passer domesticus*
Mourning dove	*Zenaidura macroura*
Crows	*Corvus brachyrhynchos*
Comorants	*Phalacrocorax* spp.
Killdeer	*Charadrius vociferus*
Avocet	*Recurvirostra america*

Gophers were available and consumed year round, although at greater frequency in fall and winter. Ground squirrels curtailed activity during the wanner temperatures of summer (Baudinette 1972) and may have been less available to the foxes. Ducks were commonly available in urban parks and golf courses. Ducks and song birds were taken in greatest quantities in spring and summer and coincidental with nesting and the availability of juveniles.

The most eggs were also taken in the spring. Some eggs may have been domestic chicken that were obtained from backyard coops or purposely fed to the foxes by humans. The relatively high frequency of eggs in the spring is probably indicative of their depredation on ground nests rather than human provided chicken eggs. Preliminary lab work indicates that shell fragments in the scat are under represented in the scat compared to hair, feathers, or bone (Golightly, unpublished data).

Seeds in the scat probably represented the ingestion of fruit. The urban environment includes ornamental and exotic plants that produce fruit at different times of year. Figs *(Ficus* spp.) were common on golf courses which were frequented by the foxes (Lewis et al. 1993). Additionally, there were remnant agricultural fields that provided fruits at different times of the year (foxes were observed eating strawberries in an agricultural field).

Mollusks and crustaceans were available at ponds in parks and golf courses. Additionally, flood control channels typically had standing water which could have been sources of these invertebrates.

More than half the fecal remains contained human associated materials (e.g., paper, foil, etc.); these materials were regular and frequent in the scat. This indicated human supplied food at all sites and seasons. Some of these materials probably came from scavenging in garbage containers. However, these remains also came from purposeful feeding by people. We noted feeding occurred at all sites and varied from dried dog food to restaurant leftovers including ribs, steaks, and other high protein supplements. Dog food provided for pets but inadvertently supplied to foxes could not be detected by our techniques.

For the one fox feeder who weighed his daily supplement to the foxes, we made calculations of the percent of the foxes' diet that was human provided. We used energy values for daily existence for red fox (Sargeant 1978), coyotes *(Canis latrans)* and kit fox *(Vulpes macrotis)* (Golightly 1981, Golightly and Ohmart 1983) and adjusted the energy values to body weight of our red foxes (Lewis et al. 1993). We then calculated the wet-weight of prey required per day (energy values from Ball and Golightly 1992) to meet these energy requirements. In most cases the supplements provided by people had higher digestibility than natural prey (no fur or feathers) on wet-weight basis. Estimates of daily food intake ranged from 0.27 to 0.32 kg per fox per day, depending on the source for the energy requirements. To put this in perspective, we calculated how this energy requirement would be met for the population of red foxes at Mile Square Park. Yaeger and Golightly (1993) estimated that 46 red foxes lived at Mile Square Park in the summer of 1992 (the period during which we measured the supplemental feeding). If each fox required 0.27 to 0.32 kg, 46 foxes would require 12.4 to 14.7 kg of food. The foxes at Mile Square Park received 7.1 kg daily from one feeder, or 57 % to 48 % of their daily food needs (alternatively this can be considered as 22 to 26 of the 46 foxes being exclusively provided food by this one feeder). There were other sources of supplemental feeding at this site including other feeders, occasional picnics (several thousand people could visit the park on a single day) and an on-site restaurant whose contributions to the foxes were not measured or considered in the calculations. The fox population at this site may have been larger than could be supported without supplemental feeding.

The ability to identify small feathers or other evidence to exact species was difficult. Although duck and song bird feathers declined into winter, the frequency of "bird remains" was as high in winter as spring. There was a greater number of unidentifiable remains in winter. It should not be expected that all species are equally identifiable and as the diet changed seasonally, our ability to make positive identifications to the species level also changed. Consequently, it is important to use both the individual species patterns and the inclusive taxonomic groupings (birds, mammals, etc.) in making comparisons.

Cache data are also important in identifying specific species consumed. Our data from caches were similar to the data from scat for mammals and birds. However, positive species identification was more common at caches. Conversely, caches could not be quantified nor could meaningful comparisons be made between seasons. Cache data were also biased towards detection and identification of larger prey items.

It is important to be careful of inferences drawn from frequency data (Lockie 1959). Because of differential ingestion of soft parts, differential digestion of food types, and unknown total biomass consumed, it is inappropriate to make detailed between species comparisons. Rather what can be inferred from the frequency data is a pattern of the regularity with which some food types are ingested, especially across seasons. Further, some items (e.g., dog food) may be missed entirely or under represented (e.g., eggs) in the fecal remains.

CONCLUSIONS

Introduced red foxes regularly consumed native birds, bird eggs, and mammals. The potential impact of this predation on native species with restricted ranges and population numbers can be estimated. Managers have often made anecdotal arguments that a single red fox could destroy most of the production in a nesting colony; for those species with restricted ranges or low population numbers this could have negative consequences. To examine the question of potential impact, we calculated the time (in days) for one red fox to completely destroy the productivity of least tern colonies in Orange County (Table 3). For these calculations, we assumed an average clutch size of 1.9 eggs per pair (R. Jurek, personal communication), that all pairs had nests, that all adults survived, and that all eggs hatched. These assumptions probably resulted in an overestimation of the number of chicks hatched. Massey (1974) reported that newly hatched least tern chicks weighed 6 g. Using our previous calculation for the amount of food required, a

Table 3. Potential damage to least tern colonies in Orange County, California caused by introduced red fox. Fox nights are the calcualted number of nights for a single fox to completely consume the colony. It was assumed in the calculations that foxes fed exclusively on the tern chicks and that the calculated clutch total was a maximum production for the number of tern pairs in the colony. Number of pairs and number actually fledged are 1993 data from California Department of Fish and Game (R. Jurek, personal communication).

Colony Location	Pairs	Fledged	Calculated Clutch[a]	Fox Nights
Huntington Beach	234	157	445	10
Seal Beach	198	364	376	8
Upper Newport	50	<20	94	2
Bolsa Chica	155	<47	294	7

[a]Assumes: Clutch size = 1.9, all pairs reproduce, no predation on adults, no other source of mortality or egg loss.

single fox would consume 45 to 53 chicks per day if ingesting exclusively least tern chicks (an exclusive diet may be realistic where nests are concentrated, especially on islands). In 1993, predation at this rate would have destroyed the colonies in 2 to 10 days. Obviously, if two foxes were feeding in a colony, the rate of depredation would double. Foxes feeding young would also increase the food requirement and the depredation rate in the colony.

Lewis et al. (1993) demonstrated that foxes at considerable distance (> 13 km) from the nesting colonies could disperse into the sensitive wetlands which contain these colonies. Consequently, it is reasonable to assume that dispersing foxes could have significant impact unless the birds are protected or the foxes removed immediately upon entering the sensitive site.

It is important to note that red foxes consumed natural prey in spite of extensive supplemental feeding. Supplemental feeding may actually exacerbate the risk to sensitive areas. For example, half the fox population at Mile Square Park was supported by supplemental feeding. Mile Square park was within potential dispersal distance to all the sensitive wetlands in coastal Orange County. The role of Mile Square Park as a source of dispersing individuals would be greater with a larger population size supported by supplemental feeding. However, a sudden cessation of supplemental feeding at Mile Square Park could also result in the movement of a large number of foxes at the present population size.

ACKNOWLEDGMENTS

This project was funded in part by the California Department of Fish and Game and the U.S. Fish and Wildlife Service. Special thanks to R. Jurek and K. Smith for facilitating portions of this project. J. Longcrier, S. Itoga, K. Henderson, and R. Wachs dissected the scat.

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