PATTERNS OF FOOD ITEM USE BY ISLAND FOXES ON SAN NICOLAS ISLAND

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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EXECUTIVE SUMMARY

Patterns of food item use by island foxes (*Urocyon littoralis dickeyi*) were assessed on San Nicolas Island (SNI) during 2006-2012 and during 2015-2018. Our objectives were to: (1) determine whether annual patterns of food item use differed between the 2009-2012 and 2015-2018 sampling periods, (2) determine whether any differences in current food item use patterns might be related to recent events, particularly the decline of sea fig (*Carpobrotus spp.*) or the initiation of habitat restoration efforts, (3) determine whether food item use varies spatially across SNI, (4) determine whether food item use varies among fox age classes, and (5) use these results to develop recommendations for the management and conservation of island foxes on SNI and other islands.

We analyzed 632 scats collected from October 2015 to December 2018. Foxes on SNI continued to exploit a variety of food items. Item use patterns generally were similar between the 2009-2012 and 2015-2018 sampling periods. Items occurring frequently included deer mice (*Peromycus maniculatus*), terrestrial snails (native and non-native), various beetles and their larvae, silk-spinning sand crickets (*Cnemotettix spp.)*, Jerusalem crickets (*Stenopalmatus spp.*), European earwigs (*Forficula auricularia*), and fruits of prickly pear cactus (*Opuntia spp.*), sea fig, and Australian saltbush (*Atriplex semibaccata*). Use of non-native items continued to be high on SNI, where foxes may be at least partially dependent on these items. In 2017 and 2018, the frequency of occurrence of snails was lower than in any other year, possibly related to a drought-induced die-off of sea fig that provides habitat for non-native European garden snails (*Helix aspersa*). In 2018, the occurrence of prickly pear cactus fruits was higher than any other year and may be related to plantings of cactus associated with habitat restoration efforts.

No obvious spatial patterns of item selection by foxes were detected in our examination of scats from four different zones on the island and scats from 12 trapping grids associated with annual fox population monitoring. Most items are likely present, although at varying levels, in each zone and grid. Also, fox movements and defecation outside of zones or grids where foods were consumed may have confounded results.

Finally, no obvious differences in food item use among 5 age classes of foxes were detected. Extensive overlap among classes with regards to the actual ages of foxes would make the detection of any age-related differences difficult.

The following recommendations are offered: (1) continue to restore natural habitats to increase the abundance and diversity of foods available to foxes, (2) reduce non-native species gradually concurrent with enhancing or restoring native food items, (3) monitor food item use periodically to identify changes in foraging patterns and adjust management strategies accordingly, and (4) consider monitoring the abundance of certain key foods to better understand the dynamics between resource availability and fox abundance.

INTRODUCTION

Island foxes (*Urocyon littoralis dickeyi*) on San Nicolas Island (SNI) are listed as Threatened by the state of California and are a Federal species of conservation concern (U.S. Navy 2015). Due to inherent space and resource limitations associated with an insular environment, this population is relatively small and therefore vulnerable to extinction. Thus, annual monitoring of population demographics and ecological attributes that can influence these demographics is warranted to help provide early warning of population declines that could lead to extinction.

Food item use by foxes is an ecological attribute of acute interest to managers on SNI. This attribute is significant because the availability of foods can fluctuate markedly depending upon environmental conditions, particularly annual precipitation (e.g., Cypher et al. 2017). When food resources become limiting, detrimental effects such as reduced production of young, reduced physical condition, deaths from starvation, and population decline have all been observed among foxes on the island (F. Ferrara, U.S. Navy, personal communication). If these effects are sufficiently prolonged and severe, the population could experience a bottleneck situation where it is further imperiled by very small size and loss of genetic diversity (Frankham et al. 2017). Such an event appears to have occurred at least once previously on SNI in the 1970s when the number of foxes may have been as low as 20 individuals (Coonan et al. 2010).

Historic events on SNI likely have profoundly affected the types and dynamics of foods available to foxes. In the 1800s, sheep were brought to the island and at one time exceeded 30,000 in number (Schoenherr et al. 1999). Over-grazing by the sheep defoliated much of the island and caused severe erosion. Thus, many native fruit-producing plant species were eliminated or significantly reduced, as was food and cover for animal prey used by the foxes (e.g., mice, lizards, birds, and insects). Concomitantly, many non-native species colonized SNI, some of which have been used extensively by foxes for food. These include ice plant or sea fig (*Carpobrotus spp.*), Australian saltbush (*Atriplex semibaccata*), myoporum (*Myoporum laetum*), European garden snails (*Helix aspersa*), and European earwigs (*Forficula auricularia*) (Cypher et al. 2014, 2017, 2018). Among all of the islands with foxes, fox diets on San Nicolas have the largest proportion of non-native items, and the dependence of foxes on these items is significant (Cypher et al. 2014, 2018).

Food item use by island foxes on SNI was examined during 2006-2012 as part of a multi-island analysis (Cypher et al. 2014) and also as part of an assessment of the effects of feral cat removal on foxes (Cypher et al. 2017). Recently, several events have occurred that potentially could have affected island fox food use. Beginning in 2008, fox abundance began declining and was particularly marked during the drought conditions experienced from 2011 to 2015. The population declined by about half, which may have reduced intra-specific competition for foods. Coincident with the drought, mortality of sea fig (ice plant) on SNI has been high. This could have impacted not only the availability of sea fig fruits, but also that of European garden snails that are commonly found on the sea fig. Additionally, ecological restoration activities recently were initiated on SNI in an effort to restore native communities and improve habitat quality. Over 30,000 individual plants from at least 27 different native species have been propagated and planted, including one (*Opuntia spp.*) that produces abundant fruits that are readily consumed by foxes (F. Ferrara, U.S. Navy, personal communication). All of these events could have influenced patterns of food use by foxes.

Additional island fox scats were collected during 2015-18 and analyzed. Some of these results were reported in Cypher et al. (2018). The goal of this project was to further examine patterns of resource use by island foxes with specific objectives being to:

1. determine whether annual patterns of food use differed from the 2006-2012 results,
2. determine whether any differences in current food use patterns might be related to recent events, particularly the decline of sea fig and habitat restoration efforts,
3. determine whether food use varies by region on the island and also examine food use among trapping grid locations,
4. determine whether food item use differs among age classes, and
5. use these results to develop recommendations for the management and conservation of island foxes on SNI and other islands.

STUDY AREA

SNI comprises 5,896 ha and is located in the Pacific Ocean ca. 100 km off the coast of southern California (Fig. 1). The island largely consists of an elevated sandstone plateau with steep slopes dropping down to the shoreline (Schoenherr et al. 1999). Maximum elevation is 277 m. Climate on the island is relatively arid with annual precipitation averaging ca. 20.0 cm (C. Drost, USGS, unpublished data).

SNI is managed by the U.S. Navy and is used for missile testing and other military support activities (U.S. Fish and Wildlife Service 2009). The island is closed to the public; access is limited to Navy personnel, federal civil servants, and contractors. Large portions of the island are regularly closed due to military operations and to protect sensitive environmental and cultural sites.

Large portions of the island are sparsely vegetated due to a combination of arid conditions and the persisting effects of past overgrazing by domestic sheep (U.S. Navy 2015). SNI has 139 native plant species (Schoenherr et al. 1999). Primary vegetation communities are mixed coastal scrub, barren or sparsely-vegetated badlands, and grasslands dominated by non-native Eurasian annual species. The non-native grasslands and barren or sparsely-vegetated areas make up about 36% of the land cover on the island. Coastal scrub covers an additional 42%, but much of this community is degraded by encroachment of non-native species (Junak 2008). Dominant plants include coastal goldenbush (*Isocoma menziesii*), giant coreopsis (*Leptosyne gigantea*), bush lupine (*Lupinus albifrons*), coyote brush (*Baccharis pilularis*), and non-native grasses, particularly slender wild oats (*Avena barbata*), ripgut brome (*Bromus diandrus*), and foxtail barley (*Hordeum murinum*). Less common, but important, native shrubs include California sagebrush (*Artemisia californica*), buckwheat (*Eriogonum grande*), California boxthorn (*Lycium californicum*), prickly-pear cactus, and coastal cholla (*Opuntia prolifera*). Among terrestrial vertebrates, only two species of mammal (deer mouse [*Peromyscus maniculatus*] and San Nicolas Island fox), three species of herpetiles (Island night lizard [*Xantusia riversiana*], side-blotched lizard [*Uta stansburiana*], and southern alligator lizard [*Elgaria multicarinatus*]), 15 species of breeding land birds, and five species of sea birds reside on SNI (Schoenherr et al. 1999).

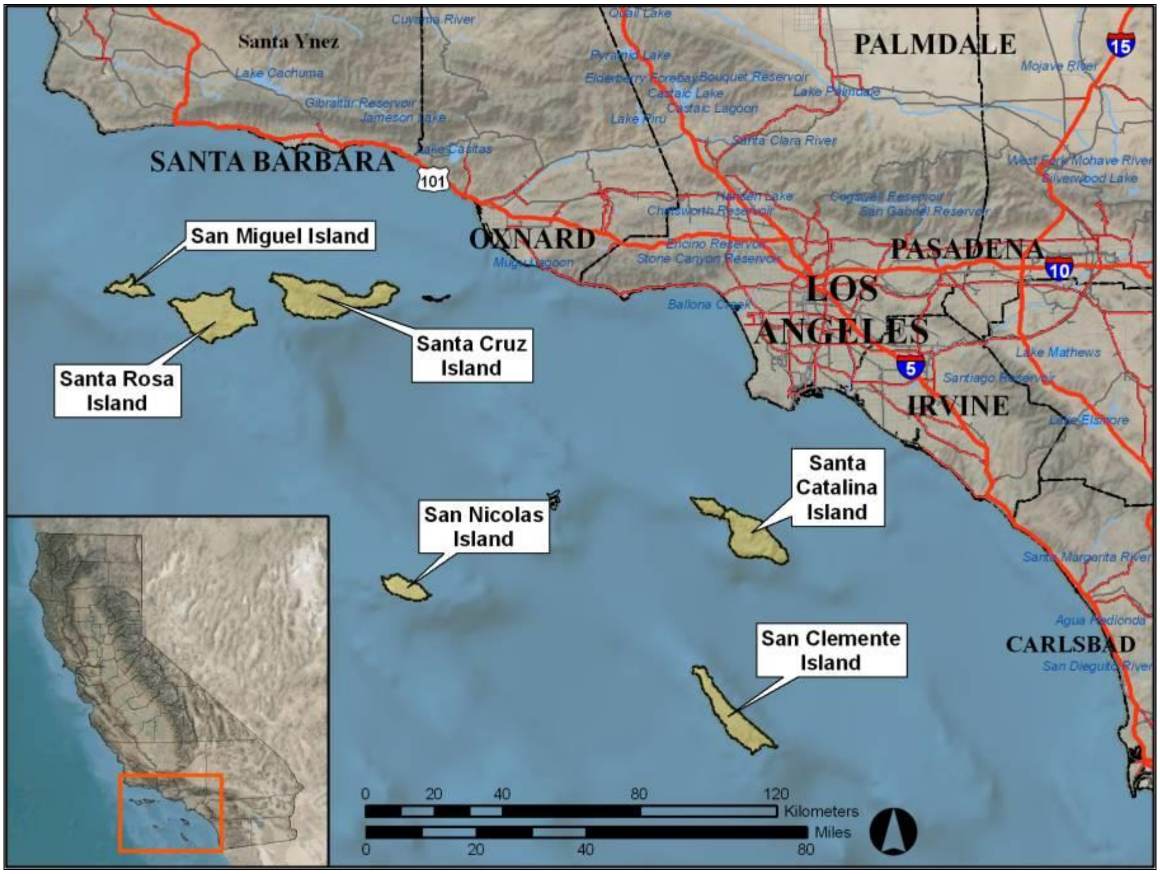

Figure 1. Location of San Nicolas Island and the other islands on which island fox populations are present off the southwestern coast of California.

METHODS

To examine long-term trends in food item use by island foxes, scats were collected monthly during October 2015 to September 2017 by biologists working on the island. Scats were located opportunistically, primarily along roads, and an effort was made to collect scats from throughout the island. After September 2017, scats were only collected during October-December at trap locations during annual fox monitoring (see below). Food item use during 2015-2018 was compared to use during 2006-2012. The 2015-2018 data were summarized by year; a year was defined as October-September to correspond with annual precipitation patterns and their concomitant effects on annual food item availability.

Use of prickly pear cactus fruits, sea fig fruits, and terrestrial snails was examined for all years to determine whether recent events (i.e., cactus plantings, sea fig die-off) affected availability and use of food items. Data were only available for the period October-December in 2017 and 2018, and so data from this same period was used for the other years as well (i.e., 2006-2011, 2015, and 2016).

To examine spatial variation in item use by foxes, SNI was divided into 6 "zones" (Fig. 2) based on habitat characteristics (U.S. Navy 2015). Zones 1 and 2 are characterized by sand dune communities with Zone 1 being coastal and more windswept and Zone 2 being more interior with denser vegetation. Zone 3 is generally an interior plateau characterized by non-native grassland communities. Zone 4 consists of coastal bluffs and plateaus characterized by coast scrub communities. Zone 5 is characterized by highly eroded rugged terrain that is sparsely vegetated. Scats collected during 2006-2012 were assigned to a zone and food item use by foxes was compared among zones.

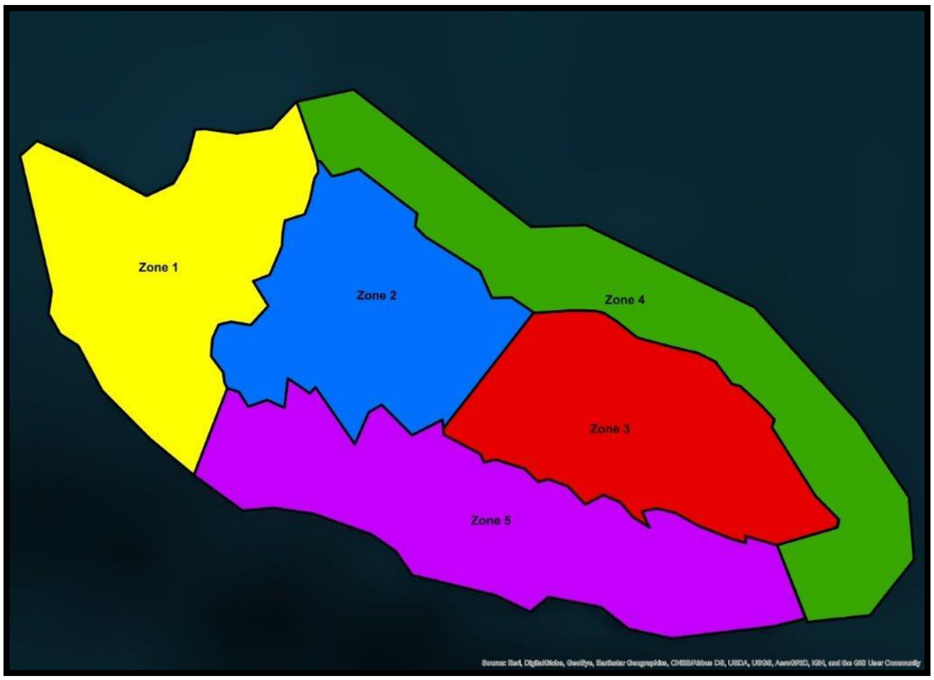

Figure 2. Zones used to conduct a spatial assessment of island fox food item use on San Nicolas Island, CA.

To further examine spatial variation in use of food items by foxes, scats were collected from animals captured during annual population monitoring conducted in October-December in 2016, 2017, and 2018. Live-trapping was conducted on 12 trapping grids distributed across the island (Fig. 3). Item use was compared among grids for all years combined.

Finally, item use by different age classes of foxes was examined using the scats collected from animals trapped during the annual monitoring in 2016, 2017, and 2018. Captured foxes were assigned to one of five age classes (i.e., 0, 1, 2, 3, or 4) based on tooth wear. Trapping methods and age-class assignment are detailed in H.T. Harvey (2017). Item use was compared among age classes for all years combined.

For all of the comparisons above, scat samples were collected into paper bags and allowed to air-dry. After shipping the scats to the Endangered Species Recovery Program (ESRP) field office in Bakersfield, California, the contents of each scat were carefully separated and individual food items within the samples were identified to the lowest taxonomic level possible. Mammalian remains were identified based on bone and dental fragments and guard hair characteristics. Birds were identified based on feather and foot characteristics. Insects were identified based on exoskeleton characteristics. Fruits were identified based on seed and exocarp characteristics. Items were identified using guides (e.g., Young and Young 1992) or by comparison with online or physical reference materials.

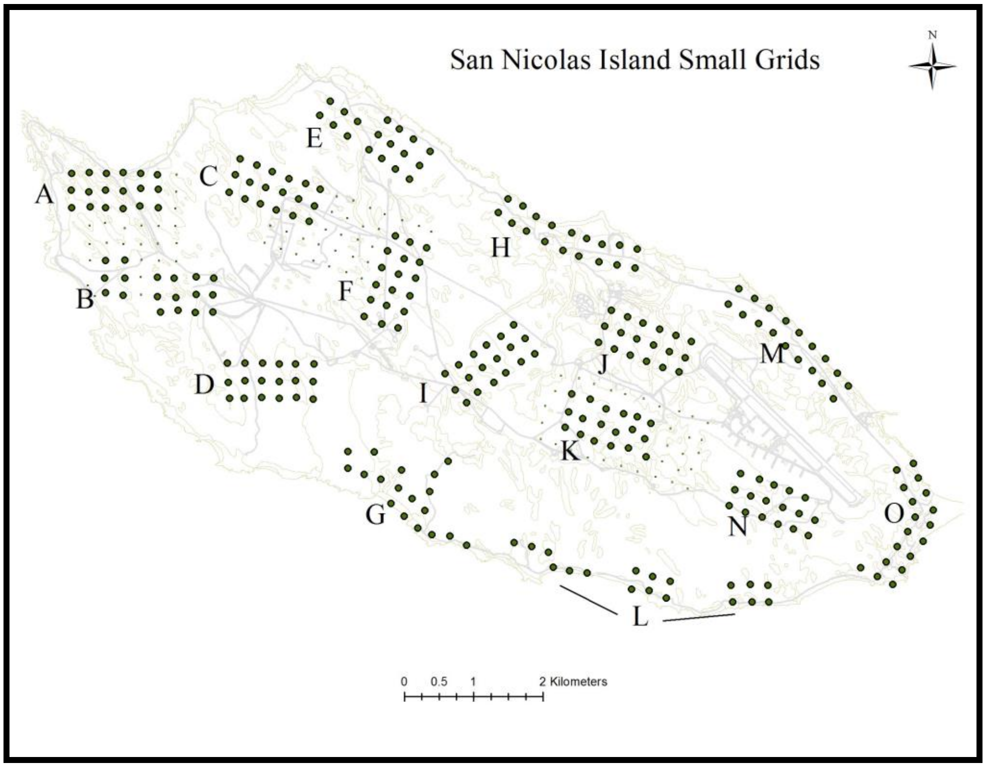

Figure 3. "Small" trapping grids on which island fox abundance is monitored annual by live-trapping, San Nicolas Island, CA.

Frequency of occurrence (FO) of items was calculated as:

$$FO_i = \frac{x_i}{n}$$

where FO_i is the frequency of occurrence of item *i*, x_i is the number of scat samples containing item *i*, and n is the total number of scat samples. FO was determined for each item in each year.

For each grouping of scats used in the comparisons above (e.g., year, zone, grid, age class), items with a FO of 10% or greater were considered to be the primary items used. Furthermore, use patterns also were compared by grouping items into four broad categories: deer mouse, arthropod, snail, and fruit.

RESULTS

ANNUAL ITEM USE

For the years 2006-2012, 1975 scat samples were analyzed while 632 samples were analyzed for the years 2015-2018. For the years 2015-2018, specific food items found in fox scats on SNI were similar to those reported previously (Cypher et al. 2014, 2017, 2018). Important dietary items included deer mice, birds (not identified to species), beetles (Coleoptera; various species) and beetle larvae, Jerusalem crickets (*Stenopalmatus spp.*), silk-spinning sand crickets (*Cnemotettix spp.*), earwigs, crustaceans, terrestrial snails, prickly pear cactus, sea fig, and Australian saltbush (Table 1). Items with a FO of 10% or greater numbered nine in three of the years and eight in one year. Thus, foxes on SNI continue to consume a diversity of items. This project provided four more years of data to supplement a relatively robust data set collected from 2006-12. Based on major item categories, food item use by foxes was generally similar between the 2006-12 and 2015-17 periods (Fig. 4).

Table 1. Food items occurring with a frequency ≥ 10% in annual island fox diets on San Nicolas Island, CA, during October 2015-December 2018. Non-native items are indicated in red. NB: Scat samples were collected in all months in during Oct 2015-Sep 2017, but only in Oct-Dec during Oct 2017-Dec 2018.

Frequency of occurrence (%) of food items							
Oct 2015 – Sep 2016		**Oct 2016 – Sep 2017**		**Oct 2017 – Dec 2017**		**Oct 2018 – Dec 2018**	
Beetles	72.9	Beetles	58.2	Deer mouse	46.9	Prickly pear cactus	54.1
Terrestrial snail[1]	53.3	Terrestrial snail[1]	34.9	Sea fig	40.6	Silk-spinning sand cricket	50.8
Deer mouse	34.1	Deer mouse	31.8	Silk-spinning sand cricket	34.4	Sea fig	34.4
Silk-spinning sand cricket	31.8	Earwig	28.0	Terrestrial snail[1]	28.1	Australian saltbush	32.8
Sea fig	31.3	Silk-spinning sand cricket	23.8	Prickly pear cactus	28.1	Terrestrial snail[1]	31.1
Earwig	27.1	Sea fig	22.2	Beetles	21.9	Deer mouse	23.0
Australian saltbush	19.6	Australian saltbush	18.0	Jerusalem cricket	15.6	Jerusalem cricket	23.0
Jerusalem cricket	10.7	Jerusalem cricket	14.9	Australian saltbush	14.6	Beetles	19.7
Bird	10.3	Prickly pear cactus	11.9			Crustacean	11.5
n = 214		**n = 261**		**n = 96**		**n = 61**	

[1] Terrestrial snails likely included native snails in addition to European garden snails.

Based on food item use by foxes in the fall, use of prickly pear fruits exhibited a marked increase from 2015 to 2018, and FO in 2018 was approximately twice as high as that recorded in any other year (Fig. 5). Use of sea fig fruits was variable; use declined somewhat in 2015 and 2016 but use in 2017 and 2018 was similar to use during the 2006-2011 period (Fig. 5). Use of snails declined during the 2015-2018 period with FO during 2017 and 2018 being the lowest among the 10 years for which data were available (Fig. 5).

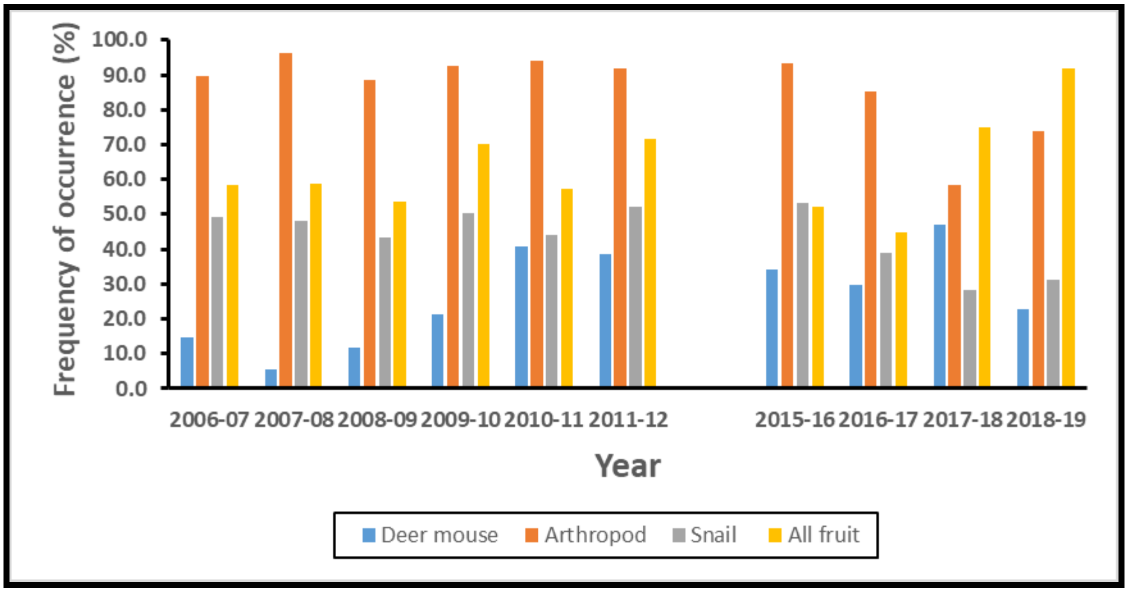

Figure 4. Annual use of food item categories by island foxes on San Nicolas Island, CA for the years 2006-2012 and 2015-2019.

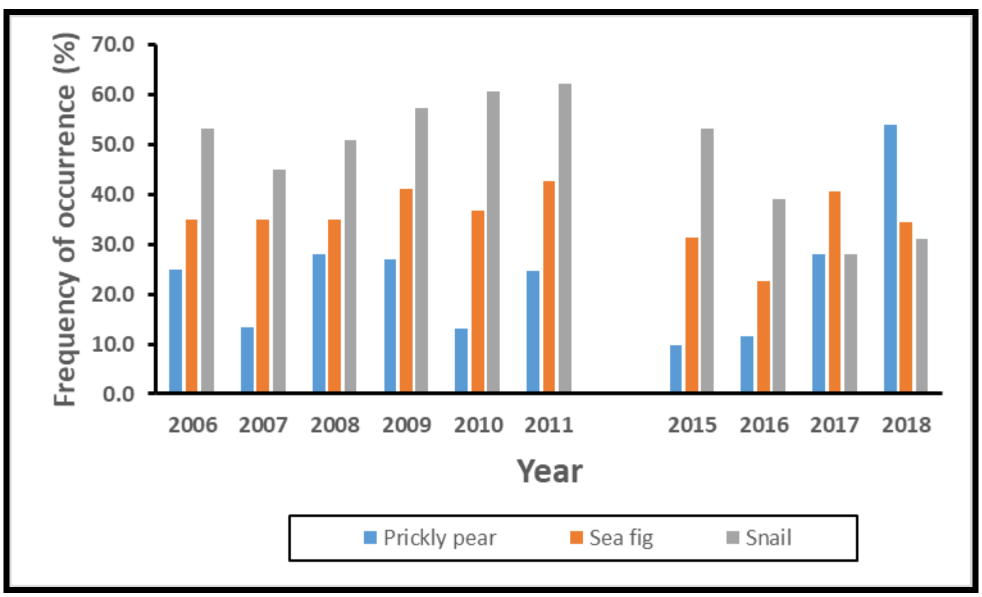

Figure 5. Annual use of prickly pear cactus fruits, sea fig fruits, and European garden snails during fall (October-December) by island foxes on San Nicolas Island, CA for the years 2006-2012 and 2015-2019.

Spatial Item Use

For the years 2006-2012, the number of scat samples analyzed for each zone was 237 for Zone 1, 551 for Zone 2, 627 for Zone 3, and 467 for Zone 4. Only 9 scats were collected in Zone 5 and therefore this zone was excluded from the data summaries. Beetles were the primary item consumed in all zones (Table 2). Snails, earwigs, and sea fig fruits usually were the next most frequently occurring items. Items with a FO of >10% numbered 5 for Zone 1, 7 for Zone 2, and 10 for Zones 3 and 4. For major item categories, FO was highest for deer mice in Zone 3, for fruit in Zone 1, for snails in Zones 3 and 4 (Fig. 6). FO for arthropods was high in all Zones.

Table 2. Food items occurring with a frequency ≥ 10% in island fox diets by zone on San Nicolas Island, CA, in October 2006-September 2012. Non-native items are indicated in red.

Frequency of occurrence (%) of food items							
Zone 1		**Zone 2**		**Zone 3**		**Zone 4**	
Beetle	89.0	Beetle	74.4	Beetle	55.7	Beetle	72.8
Sea fig	76.8	Terrestrial snail[1]	63.7	Earwig	47.1	Terrestrial snail[1]	54.6
Terrestrial snail[1]	36.3	Sea fig	52.1	Terrestrial snail[1]	33.0	Earwig	28.1
Silk-spinning sand cricket	27.4	Earwig	36.1	Australian saltbush	29.8	Prickly pear cactus	25.3
Earwig	20.7	Silk-spinning sand cricket	27.2	Deer mouse	26.6	Australian saltbush	24.4
		Deer mouse	16.7	Jerusalem cricket	25.5	Sea fig	24.2
		Australian saltbush	15.3	Sea fig	25.2	Silk-spinning sand cricket	19.3
				Silk-spinning sand cricket	18.2	Deer mouse	18.2
				Myoporum	13.9	Bird	15.6
				Lizard	11.2	Crustacean	12.6
n = 237		**n = 551**		**n = 627**		**n = 467**	

[1] Terrestrial snails likely included native snails in addition to European garden snails.

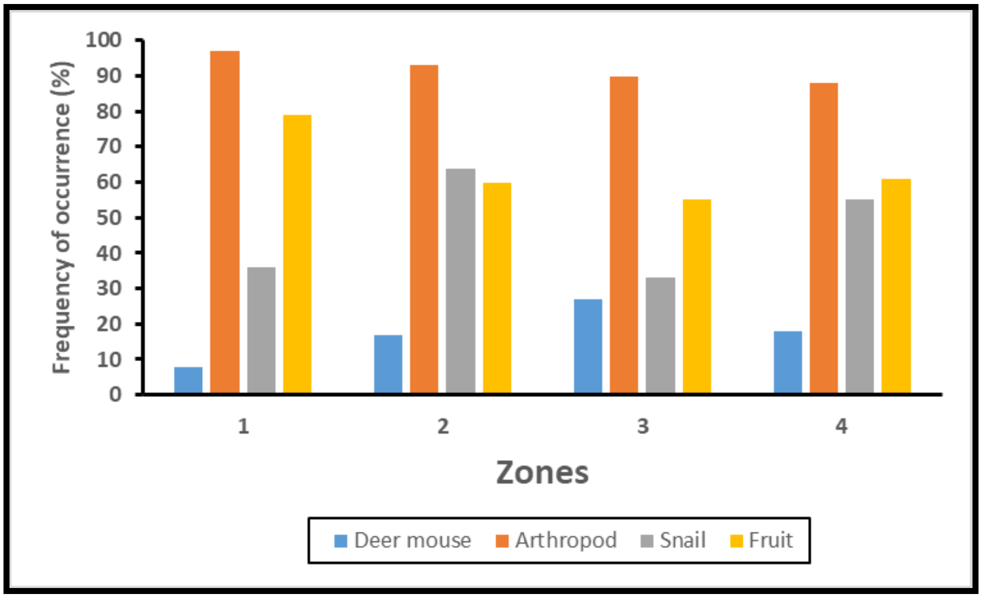

Figure 6. Use of food item categories by island foxes in four zones on San Nicolas Island, CA for the years 2006-2012.

Not unexpectedly, use of food item categories by island foxes exhibited considerable variation across the 12 trapping grids (Figure 7). Sample sizes per grid for the three years combined for which data were available from grids (2016, 2017, and 2018) averaged 21 and ranged from 7 to 45. FO of item categories across all grids ranged from 0-50% for deer mice, 27-86% for arthropods, 0-90% for snails, and 50-100% for fruit. Notable observations were no use of deer mice on Grid H, relatively low use of arthropods on Grids M and O, no use of snails on Grid A and relatively high use of snails on Grids C, E, and F. Use of fruit was relatively high on all Grids.

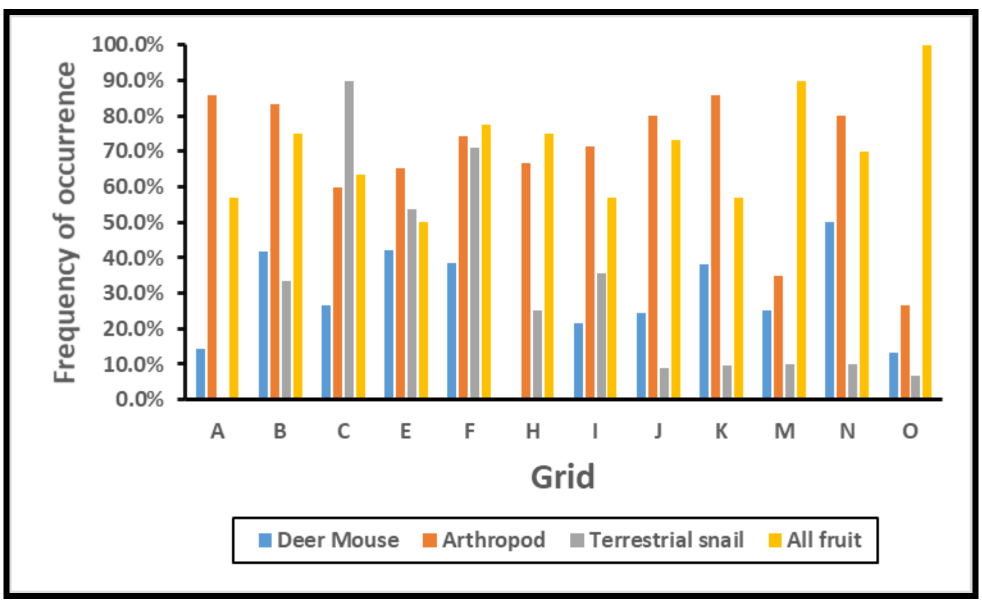

Figure 7. Use of food item categories by island foxes captured on monitoring grids on San Nicolas Island, CA for the years 2016-2018.

Item Use by Age Classes

No clear patterns were obvious when food item use was examined by fox age class for the years 2016-2018 (Table 3, Fig. 8). Arthropods and fruit were the primary items used by all age classes. Silk-spinning sand crickets and beetles were the arthropods with the highest FO for all age classes while prickly pear cactus and sea fig were the fruits with the highest FO.

Table 3. Food items occurring with a frequency ≥ 10% in island fox diets by fox age class on San Nicolas Island, CA, during 2016-2018. Non-native items are indicated in red.

Frequency of occurrence (%) of food items									
Age Class 0		**Age Class 1**		**Age Class 2**		**Age Class 3**		**Age Class 4**	
Silk-spinning sand cricket	45.2	Terrestrial snail[1]	42.9	Silk-spinning sand cricket	39.6	Silk-spinning sand cricket	53.3	Silk-spinning sand cricket	48.0
Deer mouse	43.5	Silk-spinning sand cricket	38.6	Prickly pear cactus	39.6	Beetle	35.6	Beetle	44.0
Sea fig	32.3	Prickly pear cactus	35.7	Terrestrial snail[1]	35.8	Sea fig	35.6	Terrestrial snail[1]	40.0
Prickly pear cactus	27.4	Australian saltbush	31.4	Deer mouse	24.4	Terrestrial snail[1]	33.3	Sea fig	36.0
Terrestrial snail[1]	22.6	Sea fig	30.0	Jerusalem cricket	28.3	Deer mouse	24.4	Deer mouse	20.0
Beetle	17.7	Jerusalem cricket	28.6	Australian saltbush	28.3	Prickly pear cactus	22.2	Australian saltbush	20.0
Earwig	17.7	Deer mouse	25.7	Beetle	20.8	Earwig	20.0	Jerusalem cricket	16.0
Australian saltbush	17.7	Beetle	22.9	Sea fig	20.8	Jerusalem cricket	17.8	Prickly pear cactus	16.0
Jerusalem cricket	11.3			Earwig	13.2	Australian saltbush	13.3	Earwig	12.0
n = 62		**n = 70**		**n = 53**		**n = 45**		**n = 25**	

[1] Terrestrial snails likely included native snails in addition to European garden snails.

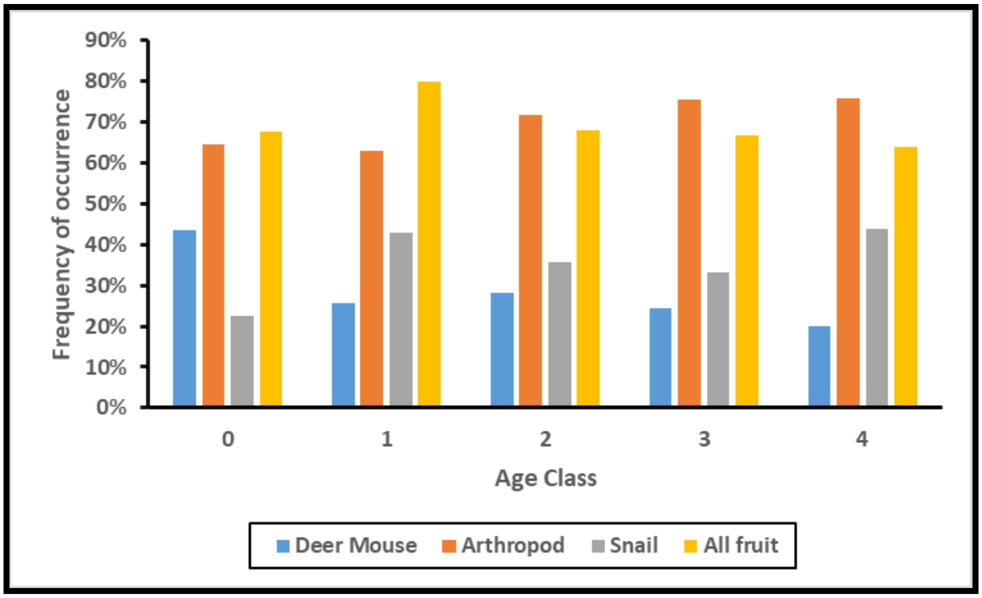

Figure 8. Use of food item categories by age class of island foxes captured on monitoring grids on San Nicolas Island, CA for the years 2016-2018.

DISCUSSION

Annual Item Use

Island foxes on SNI continue to exploit a wide variety of food items. The items occurring most frequently in scats collected in during 2015-2018 were deer mice, terrestrial snails, various species of beetles including larvae, silk-spinning sand crickets, Jerusalem crickets, earwigs, and fruits of prickly pear cactus, sea fig, and Australian saltbush. Use of non-native items continued to be high on SNI, where foxes may be at least partially dependent on these items. These results are consistent with those reported in Cypher et al. (2014, 2017, 2018).

Observed variation in use of items among years likely results from a number of sources. Availability of items varies among years and these fluctuations are strongly influenced by annual precipitation (Cypher et al. 2017). Availability also may be affected by fox density. As fox density increases in a given area or year, some items may become less available due to depletion by foxes. Food habit results also can be affected by sampling strategies. Item selection by foxes varies seasonally (Cypher et al. 2014) and can also vary spatially based on results reported in this study. Thus, differences among years in the number of scat samples collected in each season or area of the island could produce variation in food habit results among years. Finally, non-typical events can affect item availability and use by foxes. The apparent die-off of sea fig and recent ecological restoration efforts are both examples of such non-typical events.

Although some annual variation in item use by foxes was evident, item use generally was similar between the 2006-2012 and 2015-2018 sampling periods. Precipitation was variable during both periods with some relatively wet and relatively dry years. Fox abundance was considerably lower during the latter period. The island fox population began declining beginning about 2008, possibly in response to a combination of density-dependent effects coupled with a reduction in food availability resulting from several years of below average precipitation (Cypher et al. 2017; Bakker and Doak, unpublished data).

Some notable differences in item selection by foxes were observed in 2017 and 2018. Use of snails was lower during these years compared to other years and use of prickly pear cactus fruits was higher. Beginning about 2015, sea fig began to die over large areas on the island (W. Hoyer, U.S. Navy, personal communication). This die-off may have been attributable to consecutive years of relatively low precipitation from 2011 to 2016. European garden snails commonly inhabit sea fig, and thus their abundance may have declined as well, as did use of snails by foxes. The increase in use of prickly pear fruits potentially could be a response to increased availability associated with on-going ecological restoration efforts in which several thousand prickly pear cactus plants have been out-planted on the island.

SPATIAL ITEM USE

In general, there were no strong spatial patterns of item use. As described in the Methods, there are some differences in ecological communities among zones, but with a few exceptions (e.g., no marine resources in Zones 2 and 3), most items used by foxes occur in all of the zones, although the relative abundance of each item varies among zones. Consequently, item selection was not markedly different among zones. Also, because of the relatively small size of SNI, foxes can easily consume items in one zone and defecate the remains of those items in another zone, which confounds the data.

Similar comments apply to the data from the trapping grids. During the annual trapping efforts, foxes were documented moving between and being captured on multiple grids (H.T. Harvey 2017). Thus, scats collected on a given grid may not have always represented the remains of food items consumed on that grid. However, one notable result was the frequent use of snails on Grids C, E, and F. These grids all occur in an area where European garden snails tend to be abundant (F. Ferrara, U.S. Navy, personal communication).

ITEM USE BY AGE CLASSES

No obvious differences were detected in use of items by fox age classes. Some of the potential differences that might have been expected include higher use of items that are easier to acquire, such as fruits and arthropods, by very young and very old foxes and lower use of items that might be more difficult to acquire, such as deer mice, birds, and lizards, by these same young and old foxes. However, no such differences were found. Possibly, there may not be much difference among items with regards to difficulty of acquisition by foxes. Also, the scat samples were collected in the late fall/early winter (October-December) by which time young of the year foxes have gained considerable experience foraging for themselves. Thus, most items may be no more difficult for them to acquire than they are for other age classes.

Finally, the “age classes” are very general categories at best that overlap considerably with each other with regards to the actual ages of foxes. Foxes are assigned to an age class based on the degree of wear on the upper first molar (H.T. Harvey 2017). However, tooth wear patterns apparently vary markedly among SNI foxes. Consequently, although Age Class 0 includes only young of the year, Age Class 1 includes foxes 1-4 years old, Age Class 2 includes foxes 1–6 years old, Age Class 3 includes foxes 1–6 years old, and Age Class 4 included foxes 2–9 years old (Hudgens et al. 2015). This extensive overlap among age classes confounds the data and limits the utility of age class comparisons. The comparisons probably would only be valid if item selection varied by tooth wear, but the data did not provide any evidence for this.

RECOMMENDATIONS

The recommendations below are similar to those offered in previous reports and publications.

1. Protect and restore natural habitats to increase fox food supplies

Habitat protection and restoration efforts are in effect on SNI. Such efforts should be continued and enhanced when possible, particularly any efforts that increase native plant and habitat diversity. Such efforts will increase the abundance and diversity of foods for foxes, which in turn may help to increase the security of fox populations by ensuring more stable food supplies during resource declines associated with cyclic and stochastic events or climate change, particularly if different food items are affected disproportionately by such events.

2. Exercise caution when reducing or eliminating non-native items

Restoring ecosystem health and integrity on the islands will involve reducing or eliminating non-native species where practicable. On SNI, where non-native species are being used extensively by foxes for food, removal of these species should be conducted cautiously and slowly to avoid adverse impacts to foxes. Ideally, such efforts should be conducted in conjunction with the restoration of native food items to compensate for the loss of the non-native items.

3. Periodically monitor food item use by foxes

Habitat conditions on SNI are changing, particularly as a result of restoration efforts. Accordingly, the diversity and abundance of foods will change with evolving habitat conditions. Food availability also could change with increasing fox numbers and the associated increase in exploitation pressure on food resources. To better understand these dynamics and gather information that may assist in fox conservation, food item use by foxes should be monitored periodically. Annual monitoring would be ideal, but if funding is limited, periodic point in time monitoring would still be beneficial.

4. Monitor availability of food resources

Because island foxes use a diversity of foods, monitoring the availability of all food items would not be practical or necessary. However, it might be helpful to annually assess the abundance of certain key foods, such as deer mice, beetles, Jerusalem crickets, sand crickets, and fruits of prickly pear cactus and ice plant. Such monitoring probably could be designed in a manner as to not be overly costly or time-consuming. Monitoring the availability of select key items could provide early warnings of food shortages associated with reductions in one or more items. Such monitoring concomitant with on-going fox population monitoring would provide insights into the dynamics between resource availability and fox abundance.

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