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Research Article

Diet analysis of coyotes at the edge of their expanding range in Long Island, NY

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Abstract

Coyotes (*Canis latrans*) have only recently spread from mainland New York State into the large and highly urbanized islands of New York Harbor, including the over 3500 km^2 Long Island. Here, we present the first data collected on the diets of some of the first coyotes to colonize central and eastern Long Island. Vegetation, northern raccoons (*Procyon lotor*) and cottontail rabbits (*Sylvilagus* sp.) were the most common food items overall; though prey assemblages did vary by site coyotes consumed an array of small mammals everywhere. No domestic cats and dogs were found in our samples. Anthropogenic items were limited (paper, plastic, etc. was present in $<$10% of all scats and $<$ 4% of all food items) as well. White-tailed deer (*Odocoileus virginianus*), domestic cats (*Felis cattus*), and birds appeared less frequently in Long Island scat than in NYC, while raccoons and cottontails appeared more frequently. In the future greater effort should be made to identify avian remains more precisely because bird remains were present in over 20% of scats from some of our sites. This information is a valuable first step in exploring potential trophic effects of coyotes in this new area, providing information on coyote ecology to a local community, and fostering better human-wildlife coexistence as millions of Long Island residents become aware of their new neighbors.

Key words **coyote, urban wildlife, diet, scat analysis**

Introduction

Coyotes (*Canis latrans*) have drastically expanded their range over the last century from a pre-1900 distribution limited to western North America to a present range across nearly all of the continent and, recently, even reaching the borders of South America (Hody and Kays 2018). Within this expanding continental range, coyotes have also colonized many types of novel landscapes, notably urban areas. This includes somewhat "green" suburban areas (Peterson *et al.* 2021) and into the most densely populated and built areas of major cities, such as New York (Nagy *et al.* 2016, 2017, Henger *et al.* 2020), Chicago (Hance Ellington and Gehrt 2019), and Los Angeles (Adducci *et al.* 2020).

Species that flourish in urban areas are often those that have broad diets and can make use of available and atypical resources, i.e. generalists. In addition to making use of novel anthropogenic food items, urban predators may encounter different assemblages of prey species among greenspaces in an urban landscape (Sugden *et al.* 2021, Fischer *et al.* 2012, Gámez *et al.* 2022). Coyotes are no exception to this pattern and eat a tremendous breadth of food items across their range. Their most common food items tend to be small mammals, but many studies have documented large game such as white-tailed deer (*Odocoileus virginianus*); meso-mammals such as northern raccoons (*Procyon lotor*); birds and bird eggs; reptiles; aquatic/marine items including fish and shellfish; invertebrates; and vegetation including fruits, seeds, and mast (Jensen *et al.* 2022, Hayward *et al.* 2023, Williams *et al.* 2023). In developed areas, they also make use of

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anthropogenic food sources including garbage, pet food, and pets and livestock; though the extent to which this occurs varies (Morey *et al.* 2007, Larson *et al.* 2020, Sugden *et al.* 2021, Raymond and St. Clair 2023).

One of the last urban areas in the continental USA that is not yet fully occupied by coyotes is New York City (NYC) and adjacent Long Island, NY (Nagy *et al.* 2017). NYC is divided into 5 counties ("boroughs") with only one, the Bronx, lying on the southern tip of mainland of New York State. Coyotes have been present and have successfully denned in two Bronx parks in 2012, to four parks in 2014 (Nagy *et al.* 2016), and have since expanded to at least six by 2024 (Nagy, unpub data). The other boroughs of NYC are islands and reaching them requires dispersing coyotes to swim across the turbulent waters of New York Harbor or walk across high-elevation and heavily trafficked bridges. While a few coyotes have been recorded in all 5 boroughs, it has taken over a decade for coyotes to cross the waters of New York harbor, find suitable sites for territories, find mates, and in turn breed on these islanded portions of the NY metro area (see Nagy *et al.* 2017 for an early summary).

The largest island in the region, Long Island, lies south/southeast of the Bronx and offers a large area and an urban-to-rural gradient of human development running west to east, from the NYC boroughs of Brooklyn and Queens, which lie on the western end of the Island, to the separate counties of Nassau and Suffolk in the middle and east of the Island, respectively. Coyotes have never been recorded on Long Island historically (i.e. before 2000) but as of 2025 researchers know of three breeding pairs on Long Island (M. Bottini, unpub. data), with unconfirmed reports in many other locations. As coyotes colonize this large and diverse landmass it would be of interest to build a record of their diet and feeding patterns in various locations across the Island. This effort could inform local management and serve more generally as an example of how a novel predator adjusts its behavior across a spectrum of human development. The NYC-to-Long Island range expansion is an interesting reversal of what is typically observed when a mammal expands its range from less-developed areas into a developed landscape; here, we have an urban population expanding further into new suburban, exurban, and then rural areas.

This study presents the first diet information obtained from coyote scats collected from sites in Nassau and Suffolk Counties, NY. Our general objective was to determine what coyotes are eating in this new landscape and, more specifically, to describe the mammalian diversity in coyote diets to build hypotheses on the potential impact of coyote arrival on Long Island ecosystems. Further, we cultivated seeds extracted from scat to describe the fruits, seeds, and mast coyotes were consuming, a component of the omnivorous coyote's diet that is often overlooked. We also sought to provide insight into the impact of the coyote arrival on human communities by measuring the prevalence of anthropogenic food items and pets as a possible food item, and to assess the potential for control of white-tailed deer and feral cats, regarded as local environmental conservation threats.

Finally, we compared the coyote diet in these suburban environments to that of previously completed diet studies in the adjacent New York City. Two studies on the diets of NYC coyotes are available: Duncan *et al.* (2020) and Henger *et al.* (2022). The former study examined scat ($n = 159$) as we did, using morphological analysis of hair, bones, and other physical remains. Henger *et al.* (2022) used genetic analysis to determine diet composition on a larger sample that included 68 of the scats from Duncan *et al.* (2020)'s study. Henger *et al.* (2022) found the two methodologies yielded quite different results, with genetic techniques able to discern more anthropogenic items and invertebrates. We have compared our results to both of these studies.

Methods

Study area

Long Island is a 3628.6 km^2 island that lies between the coasts of New York and Connecticut (Fig. 1). It consists of four counties in New York State: Kings (i.e. Brooklyn) and Queens counties in NYC and, moving east, Nassau and then Suffolk counties. There is an overall urban-to-rural gradient from the west in Brooklyn (population density: 14 081 people/km^2) and Queens (8107 people/km^2) to Nassau (1840 people/km^2) and Suffolk (627 people/km^2). The total population of Long Island is 7.75 million (NYS Department of Health, 2018).

Historically, coyotes were not present on Long Island (Hody and Kays 2018). The first record of a resident coyote dates from 2009 in southern Queens, and researchers monitored this individual until 2019 when it presumably died (Nagy *et al.* 2016, Nagy unpub data). There was also a family of 11 coyotes in northern Queens in 2015 and 2016, but these individuals were removed by officials (Nagy *et al.* 2017, Caragiulo *et al.* 2022). Since then, other coyotes have been reported in Nassau and Suffolk, including two known pairs that successfully denned and reared pups. However, the overall population across Long Island remains low and, for now, coyote sightings remain relatively rare compared to, e.g. red fox (*Vulpes vulpes*), but are increasing.

We surveyed discrete green spaces and other areas where coyotes were known to be present during the study period. We collected scat from five overall sites, each made up of 1–4 different properties (Fig. 1 and Table 1). The first site (GT-UC) consisted of the combined properties of the Greentree Foundation (Greentree) and the Unitarian Universalist Congregation at Shelter Rock (UUCSR) in eastern Nassau County. The combined properties spanned 200 ha, including 121 forested hectares of which 83% consist of a mature Oak (*Quercus* spp.) –Tuliptree (*Liriodendron tulipifera*) forest. Greentree also features a combined 28 ha of semi-natural grassland/old fields/hay fields, and managed orchards with apple and other fruit trees. Immediately adjacent to the GT-UC site lie a coastal stream, ponds created by impoundments, golf courses, and residential areas. A pair of coyotes was well-established there during the scat collection period and was closely monitored by trail cameras (Perreault and Filipi unpub. data). The first coyote sighting at GT-UC was in November 2019, the pair formed by 2020, they had four pups in March 2021, but no new pups were seen in 2022. The pups born in 2021 remained on their parents' territory for an individual estimated time of 12, 14, 18, and 25 months.

The second site (KPP) was entirely located within King's Point Park in the town of King's Point, NY. Reports from residents and staff provided evidence that a pair, potentially with pups, held a territory at KPP since at least 2018. We were unable to obtain permission to monitor KPP coyotes with camera traps. King Point Park covers 71 ha, of which 95% is forested with red maple (*Acer rubrum*) - sweetgum (*Liquidambar styraciflua*) swamp, red maple-hardwood swamp, and other forest types. Areas adjacent to the scat collections site include residential areas, saltwater creeks, and beaches on the Long Island Sound and Little Neck Bay.

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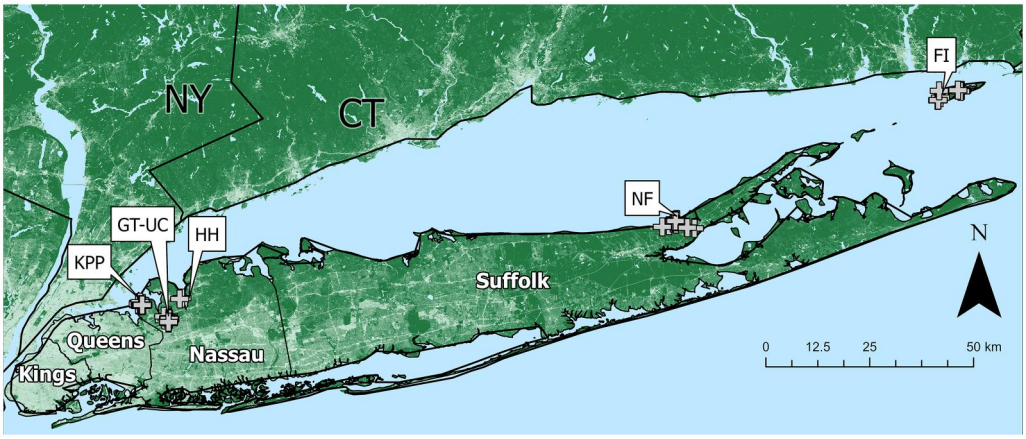

Figure 1 Locations of scat samples collected 2020–2022 in the King's Point Park (KPP), Greentree Foundation and adjacent Universalist Church (GT-UC), Hempstead Harbor and Harbor Links (HH), North Fork (NF), and Fisher's Island (FI) sites. Long Island is made up of Kings and Queens Counties of NYC and Nassau and Suffolk Counties, NY. Heat map displays the USGS National Landcover Database 2023% impervious layer (Dewitz 2023) with low to high impervious cover represented from dark to light green.

Table 1 Area, number of scats, collection dates, and distances among scats at five study sites in Long Island NY, 2020–2022.

Site	Area (km^2)	Scats	First collection date	Last collection date	Collection days	Max distance among scats	Mean Imp surface*
GT-UC	2.16	53	6/18/2020	4/18/2022	28	1821 m	28.7 (26.2)
KPP	0.70	35	7/7/2020	4/29/2022	26	919 m	24.0 (20.7)
HH	2.46	6	12/8/2020	1/16/2022	4	477 m	29.6 (28.4)
NF	3.85	40	12/27/2020	4/26/2022	26	5871 m	9.6 (17.2)
FI	12.86	15	10/16/2020	11/20/2020	7	4966 m	8.8 (14.6)
All sites	22.03	149	6/18/2020	4/29/2022	91	158 km	18.1 (23.1)

*Mean (*SD*) of percent impervious cover from the 2021 National Landcover Dataset (Dewitz 2023) in a 1.5 km buffer around the location where each scat was found at each study area.

The third collection site (HH) was located to the West and South shores of Hempstead Harbor. Reports from local residents and workers provided evidence that at least one breeding pair held a territory at HH. The collection site featured 59-ha of contiguous wet woodland, where red maple was predominant. Ponds, wet meadows, dry meadows, coastal marshes, town beaches, golf courses, covered landfill, and recreational parks were green features of the collection site, in addition to residential and industrial areas. Coyote sightings have occurred in that vicinity since 2018.

All three western Nassau County scat collection sites could be described as urban oases and were located within 7 km of each other. All were close to the NYC border, with GT-UC and KPP being <2 km from the Eastern border of Queens/NYC, and HH <5 km away. Coyotes from these sites seemed to be different individuals or of different resident pairs but were all likely recent dispersers that crossed the Long Island Sound from the Bronx. Additionally, more recent coyote sightings in eastern Suffolk were confirmed by researchers with cameras traps and scat searches by team members and volunteers. Based on these reports, we delineated a fourth site consisting of three private preserves and one state park on the northern peninsula (the "North Fork", hereafter, the NF site) that juts east off of Suffolk County. The original colonization route of any coyotes in the area of NF is not known.

Lastly, Fisher's Island, an island 18.8 km off the eastern end of Long Island and 3.2 km from the Connecticut coast, was colonized by coyotes in 2009 (P. Rafferty, Director, Henry L. Ferguson Museum, Fisher's Island, CT, pers. comm.). This 10.5 km^2 island is sparsely developed with only ~200 permanent residents–though seasonal summer population can be around 2000 people–and includes two golf courses and a small airport (H. Lanza, Town Planning Department Director, Town of Southhold, NY, pers. comm.). Most residential and commercial development is found on the island's western end. Scats were collected along trails in the grasslands associated with the airport, Parade Grounds and Hay Harbor Golf Course golf on the west end of the island; trails in the Matthiessen Wildlife Sanctuary grasslands located in the middle of the island; and the Fishers Island Club golf course on the east end. Owing to the longer time span of steady coyote presence, the Fisher's Island site (FI) likely represents another site with at least one breeding pair of coyotes, possibly more. Based on the geography, the founding individuals of the Fisher's Island population likely arrived from mainland Connecticut.

Scat collection and analysis

Scat searches in four of the five sites consisted of researchers walking hiking and game trails on a monthly or more frequent basis from June 2020 to April 2022. The exception, FI, was surveyed from October to November of 2020. Each scat was placed in a paper bag with desiccants, and stored in cool, dry conditions until they were analyzed.

Before they were examined for prey content, scats were tested to confirm their species of origin. The study took place at a time when

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the number of coyotes in Long Island was still small, and there were only a handful of locations where they were known to be established. In this context, it was critical to ensure that every scat analyzed was from a coyote. The National Genomics Center for Wildlife and Fish Conservation (USDA Forest Service, Missoula, MT, USA) tested all samples first with the 16SrRNA region of mtDNA and then, if this first screening failed, tested with the 16S region of the cytochrome b region. Scats that were not of coyote origin or for which genetic tests were inconclusive were discarded.

The remaining coyote scats were examined to identify prey remains and other dietary items (see Duncan *et al.* (2020) and Zielinski and Duncan (2004) for full details). Scats were enclosed in nylon mesh, washed and then soaked overnight in water. Fecal material was rinsed and washed off through a 500 micron sieve. All hard materials such as hair, feathers, teeth, bone, plant material, and anthropogenic objects were catalogued, separated, and dried. Dietary items of mammalian origin were then identified to species if possible, using a comparative collection from the American Museum of Natural History (New York, NY, USA) and anatomical texts (Stains, 1959, Elbroch, 2006). Bones and teeth identifications were confirmed when possible by examining the cuticles and structure of guard hairs also present in the same scat. In scats with no skeletal remains, guard hairs alone were used (Adorjan and Kolenosky 1969). In most cases, we were able to identify mammalian remains to species, with a few exceptions (see Results).

Avian remains (feathers, claws, and bones) were only identified as Aves and were not identified further. Invertebrates were identified to Order. Plants were first categorized into 3 groups: (1) leaves, stems, and woody debris; (2) grass/sedge; and (3) fruits, seeds and mast. Seeds that were not readily identifiable were further analyzed by planting them in flower pots, allowing them to germinate and grow, and identifying them by post-cotyledon leaves. Anthropogenic food items were identified by the presence of packaging materials or other garbage (leather, foil, plastic, etc.).

Two occurrence statistics were calculated for each site, based on the food items found across all scats from each respective site, and for all sites pooled together. First, the frequency of occurrence for a given food type was calculated as

$$FO_i = (n_i/N) \times 100$$

where n_i is the number of scats within which diet item i was found and N is the total number of scats for that site. Second, the percentage of occurrence was calculated as

$$PO_i = (n_i/\sum n_i) \times 100$$

Where $\sum n_i$ is the sum of n_is for all food items. PO_i measures the percentage of food item i out of all observed food items, whereas FO_i is the percentage of scats that contained food i. Both of these indices are similar but have slightly different meanings. FO_i can indicate how frequently a species feeds on a given food item across all of its meals, i.e. across all of the scats collected. FO_is do not total to 100% across food items because multiple items can appear in a single scat. Rather, it is the proportion of scats that the item was present in. PO_i is the proportion of a specific food item out of all of the observed food items, i.e. how common a food item is compared to other food items in a dataset, and does sum to 100% in a sample. We used FO_i to describe our results in most cases, but used PO_i when directly comparing proportions of different items to each other within sites.

We compared our findings to those of Duncan *et al.* (2020) who analyzed 159 scats from parks within New York City, and the NYC sites examined by Henger *et al.* (2022). We hypothesized that coyotes in the western Nassau sites and NYC would have relatively similar diets, as these areas were all patches of mixed forest and parkland within an urbanized matrix. In contrast, NF and FI were situated in less urbanized regions and had more varied landcover, such as croplands and hay fields in NF, and herbaceous wetlands and beach dunes on FI, in addition to forest. To describe site-specific variation we calculated the Morisita-Horn similarity index (Horn, 1966, Krebs, 1999) for pairs of sites, including Duncan *et al.* (2020) and Henger *et al.* (2022) NYC samples, using all identified mammal species excluding coyote, all birds (pooled), invertebrates, fruits/seeds (pooled), and all anthropogenic items (pooled). Similarity was calculated using the 'vegan' package (Oksanen *et al.* 2026) for Program R (R Core Team 2024).

Finally, 10 camera traps were deployed throughout the study period at GT-UC. They were moved seasonally to cover trail intersections, carcasses, food sources, and other areas of interest to monitor the family group living at the site. Some of our observations and selected images are included here as interesting direct evidence of feeding coyotes but were not included as data points in our formal analysis.

Results

A total of 149 mDNA-verified coyote scats were collected at the 5 sites, with 53 scats from GT-UC, 35 from KPP, 6 from HH, 40 from NF, and 15 from FI. We tallied 356 distinct food items (Table 2, Table S1, available as supplementary material at *JUECOL* online.). Of the 168 food items of mammalian origin, 90 were identified to species, 64 were identified to genus (*Microtus* sp., *Peromyscus* sp., *Sciurid* sp., and *Sylvilagus* sp.), 10 were identified to family (Cricetidae), and 4 were identified only to order (Rodentia; see Table S1, available as supplementary material at *JUECOL* online.).

Across four of the five Long Island sites, mammalian prey was the most common category of food, appearing in 85.9% of scats and making up 47.2% of all food items. The respective proportions of the important prey and food types varied quite widely from site-to-site (Fig. 2). By site, mammalian items were consistently the most common category of food at GT-UC (*POi = 43.*7%), KPP (45.8%), HH (50.0%), and NF (65.9%). In contrast, FI had an unusually low PO_i of mammalian prey (18.4%).

Coyotes ate different mammal species across different sites (Fig. 1). At GT-UC we found *Microtus* voles (*FOi = 20.*7%). *Sciurus* squirrels (*FOi = 20.*8%), and raccoons (*FOi = 26.*4%). KPP, <5 km away, had an extraordinary proportion of raccoons (*FOi = 65.*7%). and no Crecitidae. NF coyotes ate predominantly *Sylvilagus* cottontails (*FOi = 72.*5%), and *Microtus* (*FOi = 37.*5). The most common mammalian food item at FI was *Sylvilagus* with a FO_i of 13.3%.

Northern raccoons were the most common mammalian prey in the three western sites (*FOi = 42.*5%; *n* = 94). In comparison, the presence of racoon remains in scats was minimal at the NF (*FOi = 2.*5%) and FI (*FOi = 6.*5%). Complementary information was obtained during the pup feeding season when adults were more likely to carry prey. Adult coyotes were photographed on trail cameras carrying five raccoons in a span of 14 days at GT-UC in June 2023 (Fig. 3), a year when

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Table 2 Frequency of food items present in scats (FO_i%) in each Long Island site, New York, and New York City, NY, USA 2020–2022.

Food Item/Taxa/Group	GT-UC	KPP	HH	NF	FI	NYC1*	NYC2*
Mammalia	84.9	91.4	83.3	100.0	40.0	91.8	52.6
Carnivora	30.2	65.7	50.0	7.5	13.3	36.5	30.5
Mustela vison	0.0	0.0	0.0	0.0	6.7	0.0	0.0
Canis latrans	3.8	0.0	0.0	2.5	6.7	23.3	0.0
Procyon lotor	26.4	65.7	50.0	5.0	0.0	9.4	27.4
Felis catus	0.0	0.0	0.0	0.0	0.0	4.4	4.2
Odocoileus virginianus	5.7	2.9	16.7	12.5	0.0	19.5	9.5
Rodentia	52.8	17.1	50.0	52.5	13.3	35.2	34.7
Ondatra zebithicus	0.0	2.9	16.7	0.0	0.0	6.9	5.3
Microtus sp.	13.2	0.0	16.7	22.5	6.7	0.6	0.0
Microtus pennsylvaticus	7.5	0.0	0.0	15.0	0.0	6.9	12.6
Peromyscus sp.	1.9	0.0	0.0	2.5	0.0	1.3	2.1
Unknown Cricetidae	7.5	0.0	16.7	12.5	0.0	0.0	0.0
Sciurus carolinensis	17.0	14.3	0.0	0.0	0.0	10.7	3.2
Sciurus sp.	3.8	0.0	0.0	0.0	0.0	0.0	0.0
Marmota monax	0.0	0.0	0.0	0.0	0.0	1.3	0.0
Tamiasciurus hudsonicus	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Tamias striatus	1.9	0.0	0.0	2.5	0.0	0.0	3.2
Rattus norvegicus	0.0	0.0	0.0	0.0	0.0	4.4	5.3
Unknown rodent	5.7	0.0	0.0	0.0	6.7	5.0	0.0
Sylvilagus sp.	17.0	5.7	0.0	72.5	13.3	9.4	13.7
Didelphis virginiana	3.8	2.9	0.0	0.0	6.7	1.3	2.1
Blarina brevicauda	1.9	0.0	0.0	2.5	0.0	1.3	1.1
Aves	20.8	5.7	0.0	7.5	26.7	27.7	27.4
Colubridae	0.0	2.9	0.0	0.0	0.0	0.0	0.0
Insecta	9.4	11.4	0.0	0.0	6.7	18.2	33.7
Bivalvia	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Malacostraca	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Vegetation	79.2	80.0	33.3	55.0	100.0	81.1	80.0
Leaves/Plant/Woody	32.1	65.7	16.7	20.0	46.7	56.6	X
Grass	37.7	17.1	33.3	47.5	53.3	28.3	X
Fruit/seed/mast	56.6	14.3	33.3	10.0	66.7	23.9	23.6
Vitis (grape)	7.5	2.9	16.7	0.0	0.0	X	X
Pyrus (pear)	11.3	0.0	0.0	0.0	0.0	X	X
Malus (Apple)	26.4	8.6	0.0	10.0	6.7	X	X
Prunus (Cherry)	9.4	5.7	0.0	0.0	0.0	X	X
Citrus	3.8	0.0	0.0	0.0	0.0	X	X
Diospyris (Persimmon)	11.3	5.7	0.0	2.5	0.0	X	X
Rosa	0.0	0.0	0.0	2.5	0.0	X	X
Rubus	3.8	0.0	0.0	0.0	0.0	X	X
Vaccinium (Blueberry)	1.9	0.0	0.0	0.0	0.0	X	X
Unkown Fruit/Seed	20.8	2.9	16.7	0.0	60.0	X	X
Anthropogenic	17.0	5.7	33.3	0.0	6.7	26.4	64.2

*NYC1: Duncan *et al.* (2020); NYC2: Henger *et al.* (2022).

our cameras were near the rendezvous site, albeit after the scat collection period. We ran a post hoc test of the seasonality of when raccoons tended to be eaten, as perhaps during the pup-rearing season a larger prey item would represent a better investment of foraging time despite being riskier or more challenging to capture, whereas during the non-pup-rearing seasons smaller mammals would be a safer alternative. However, a chi-square test of independence indicated no significant association between pup-rearing season (May to August) and raccoon occurrence in coyote scats at our western Long Island sites ($\chi^2 = 0.25$, $df = 1$, $P = 0.61$).

The other mesomammals and small carnivores present in the study area were rarely found in the coyote diet at our study sites. Virginia opossum had a *FOi = 2.*9%, northern mink; *FOi = 0.*7%, and no remains of domestic cat (*Felis cattus*), woodchuck (*Marmota monax*), or striped skunk (*Mephitis mephitis*) were found in this study ($n = 149$ scats). At GT-UC, camera trap sequences have shown several occurrences when coyote did not engage with Virginia opossum while being within a close distance. Most of these occurrences occurred under an American persimmon (*Diospyros virginiana*) tree, where coyotes and opossums were simultaneously feeding on fallen fruits. In another instance, an adult coyote ignored a Virginia opossum after coming nose-to-nose in front of a camera (Fig. 3). American mink remains were found in 1 of 15 scats collected at FI. There were no evidence of domestic cat as a coyote food item in this study, though they were detected on trail cameras at GT-UC.

Deer was not a common food item in this study with an overall *FOi = 6.*7%, ranging from 2.3% to 16.7% among sites at the 4 sites where they were detected. No deer remains were detected at FI ($n = 15$ scats). Of these 10 scats, 5 were collected in the winter, 3 in the spring, 1 in the summer and 1 in the fall.

Avian presence in scats were only substantial at GT-UC (*FOi = 20.*8%) and FI (26.7%). Our morphological analysis did not determine what sub-taxa were present. Since 2022, two GT-UC camera trap records included the identification of Canada Geese being

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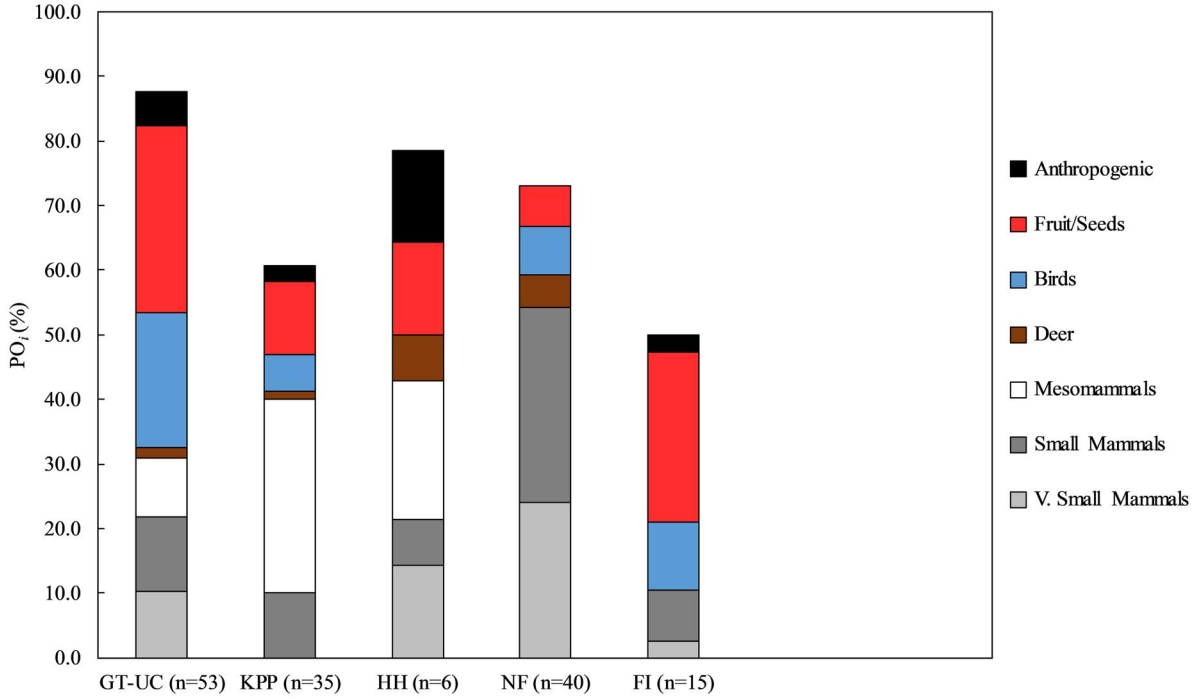

Figure 2 **%** occurrence of common prey and food categories out of all food items (PO_i) recorded at five Long Island sites and from the NYC sample of Duncan *et al.* (2020) and from Henger *et al.* (2022). Mammals were grouped by size: Very Small Mammals = < 0.5 kg (*Microtus, Peromyscus*, *Tamias, Blarina*); Small Mammals = 0.5—2 kg (*Sciurus*, *Sylvilagus*, *Ondatra*); Mesomammals = 2–20 kg (*Procyon lotor*, *Didelphis virginiana, Mephitis mephitis*); and Deer (*Odocoileus virginiaus*).

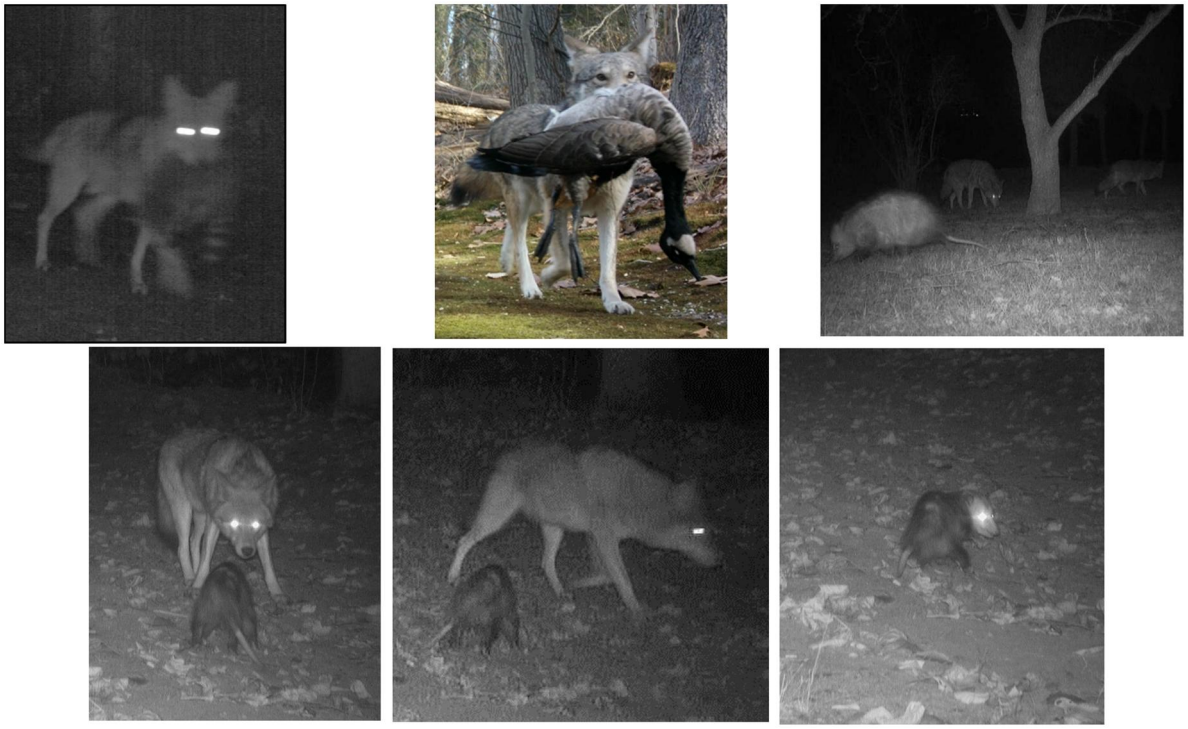

Figure 3 Coyotes were photographed by camera trap 5 times carrying raccoons at GT-UC in 2023 (top left) and twice carrying Canada Geese (top middle) in the winter of 2022 and 2025. Both of these species are larger than rodents or rabbits and can provide a substantial food. Coyotes were also photographed ignoring or avoiding opossum multiple times at GT-UC. Top right: Two coyotes and an opossum foraging on fallen fruits at an American persinnon tree. Bottom row: A series of photographs showing a coyote and an opossum encounter each other along a trail. After a brief stare-down, the coyote leaves.

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Table 3 Morisita-Horn indices of similarity of diet items (mammals excluding coyotes; birds; reptiles; invertebrates; fruits and seeds; and anthropogenic items) found in coyote scat from four Long Island sites and in NYC (NYC1: from Duncan *et al.* 2020; NYC2: from Henger *et al.* (2022)).

	GT-UC	KPP	HH	NF	FI	NYC1	NYC2
GT-UC	x						
KPP	0.58	x					
HH	0.72	0.76	x				
NF	0.41	0.17	0.19	x			
FI	0.81	0.25	0.45	0.33	x		
NYC1	0.78	0.39	0.59	0.31	0.58	x	
NYC2	0.68	0.48	0.68	0.25	0.45	0.87	x

A index of 0 would mean the locations share no species in common, and a score of 1 would indicate identical samples in assemblage and percent occurrence of each species.

carried by a coyote (Fig. 3), both during the winter when more than 80% of the local geese are wintering migrants (S. Perreault, pers. observation). We also identified a Northern Bobwhite (*Colinus virginianus*) being carried by a coyote in 2025.

Total plant matter that appeared to be eaten/partially digested was found in 109 scats (149 food items total, *FOi* = *73*.2%) and was grouped into leaves/stems/wood (*FOi* = *37*.6%), grass (36.9%), and fruits/seeds/nuts (9.2%). Of the latter, 3 of the 30 fruit/seed/nut items could be directly identified specifically as apples (*Malus* sp.). From the seeds we were able to grow and identify we found that coyotes consume several cultivated and wild fruits and berries such as *Malus* sp. (*FOi* = *14*.8%), *Diospyris* sp. (persimmon, 6.0%), *Prunus* sp. (black and/or chokecherries, 4.7%), *Vitis* sp. (grapes, 4.0%), *Pyrus* sp. (pears, 4.0%). When and where available, cultivated fruits are an easy source of nutrition for coyotes and other wildlife (Fig. 3).

Anthropogenic items were found in 14 (*FOi* = *9*.4%) scats, and included plastic (8 scats), paper (3 scats), foil (2 scats), and leather (1 scat). There was a wide range in the frequency of anthropogenic items among our sites, from 0% at NF to 33.3% at HH, though the latter may have suffered from its small sample size (6). GT-UC also had a relatively high frequency of anthropogenic items in scats (17.0%). Also, the 10 invertebrate food items we found were identified to Class Insecta from chitinous remains. During the processing of the scats we only noticed a small volume of chitinous remains in scats, when present.

We calculated the Morisita-Horn similarity index across Long Island and the NYC studies (Table 3). The western Nassau cluster of sites (GC-UT, KPP, and HH) were more similar to each other than the other sites, as expected, although GT-UC itself was quite similar to FI (CMH = 0.81). Regarding the latter, although mammals were less common in scats from FI than GT-UC, there were similar frequencies of small mammals, fruits and seeds, and birds. NF was the most dissimilar to other sites, due to the elevated occurrence of *Sylvilagus* and *Microtus*.

Discussion

Mammals overall and/or vegetation made up the majority of identified food items across all Long Island sites (Fig. 2), and this broadly concurs with Duncan *et al.* (2020) and Henger's et al.'s (2022) results and other studies of urban coyote diet (Morey *et al.* 2007, Murray *et al.* 2015, Poessel *et al.* 2017, Larson *et al.* 2020, Peterson *et al.* 2021, Jensen *et al.* 2022). However, sites differed markedly in the details. FI itself had low mammalian frequency: *FOi* = *40*% at FI versus a mean 89.9% FO_i at the other 4 sites. Vegetation was common at FI (100% of scats) but only found in 33.3% of scats at HH. Similarly, the most common prey at the species/genus level across all sites was northern raccoon (*FOi* = *28*.19%) and cottontail rabbits (*FOi* = *28*.19%) but, again, there was substantial variation across sites. Raccoons were common at GT-UC, KPP, and HH (the western Nassau sites) but were relatively rare in scats from NF and FI. The prevalence of cottontails in the dataset overall was driven by NF (cottontails were found in 72.5% of the scats from this site); elsewhere, and in NYC, they were present but not of great importance.

Among-site differences in diet are most likely reflections of what is available to the coyotes at each site, and thus coyotes are showing, once again, their ability to adapt their foraging behavior to a wide range of situations. The most unusual site was NF. There, cottontail rabbits (*Sylvilagus* sp.) were the most common prey species instead of raccoons. This area is less developed than the western portion of the island, but rather than medium-to-mature aged second-growth forest, the natural/non-impervious space there tends to be old fields, shrub/scrub areas, and agricultural land. These conditions would suggest cottontails are abundant here, and thus coyotes are taking advantage of whatever prey is most available. NF also had the highest PO_i for meadow voles (*Microtus pennsylvanicus*), potentially for the same habitat-related reasons.

The relatively high occurrence of raccoon in the diets of Long Island coyotes, at least at our western sites, was unusual (Fig. 3) compared to other coyote diet studies (Poessel *et al.* 2017, Larson *et al.* 2020, Hayward *et al.* 2023) and Duncan *et al.* (2020) NYC analysis (*FOi* = *9*.4%). However, Henger *et al.* (2022) found a similar frequency of raccoon (FOi = 27.4%) in scat from NYC using genetic analysis. As with many urban landscapes (Hadidian *et al.* 2010), raccoons are common in the NYC metro area as a whole and are the most often photographed species in NYC parks (C. Nagy, unpublished data). Coyotes in these areas could be responding simply to the high availability of raccoons in the more urban sites. We do not know if the raccoons found in our scat samples were predated or scavenged, but it seems that at least some of these occurrences were the result of predation in those sites where raccoons were so frequently consumed. In the multiple photographic observations from GT-UC the raccoon carcasses seem intact and fairly fresh (Fig. 3). However, the idea of a simple positive relationship between urbanization, abundant raccoons, and more prevalence of raccoons in the diet of coyotes is not the whole story, as GT-UC, KPP, and HH coyotes seemed to consume raccoons more than in NYC itself. While coyotes had been present in NYC parks for many years, highly-abundant raccoons in our Nassau sites perhaps have not yet adjusted their behavior in response to a new predator in their midst.

Long Island coyotes, at least in our study sites, seem to eat very little anthropogenic-sourced food overall except for some orchard fruits. The proportions of anthropogenic items found in the diets of urban coyotes have varied considerably across studies based in different cities, ranging from the majority of food sources being anthropogenic (Larson *et al.* 2020), to moderate (∼50%) amounts (Murray *et al.* 2015, Fedriani *et al.* 2001, Newsome *et al.* 2015), to a rather minor portion (<20%; Morey *et al.* 2007, Reed *et al.* 2023). These patterns can also vary seasonally, spatially, and/or among individual coyotes within the same city (Morey *et al.* 2007, Fedriani *et al.* 2001, Sugden *et al.* 2021). However, this study, and all others that use morphological

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analysis, underestimate the frequency of anthropogenic items that are totally digestible, such as any kind of processed foods or de-boned meat. Genetic analysis (Henger *et al.* 2022) can identify anthropogenic and other food items that leave no macroscopic remains and if such food sources are important to address a research question then methods that can detect those items should be employed.

Macroscopic remains of domestic animals, however, should still appear in scat with the same probability as wild prey. No remains of domestic pets, namely cats, were found in any of our scats. Given the landscape, it is likely that coyotes in most (GT-UC, KPP, and HH) if not all of our study sites had access to free-ranging cats.

The role coyotes might play as a top-down control on larger prey is a common avenue of inquiry in coyote studies in urban areas or where apex predators have been extirpated (Morey *et al.* 2007, Magle *et al.* 2014, Peterson *et al.* 2021, Jensen *et al.* 2022, Heinrich *et al.* 2025). First, it has been hypothesized that coyotes may help limit white-tailed deer, which have increased to concerning densities in many urban and suburban areas across their range. Deer are very common in Suffolk County and have a spotty distribution in Nassau County but were present at all sites except FI. While deer remains were also found in the coyote scats at these four sites, the species was not a substantial portion (*FOi* = 6.7%, *POi* = 2.5%). Generally, coyotes do not limit deer (Bragina *et al.* 2019) in areas where deer densities are already high, but exceptions may occur locally (Chitwood *et al.* 2015). Coyotes do predate deer fawns frequently in many places, even if the level of predation does not impact population dynamics. It is also thought that predation of deer might increase in winter and early spring, when deer may be weaker, struggle to move through deep snow, and/or when coyotes have fewer options. We did not observe enough deer in our sample to perform any formal analysis, but most of the deer we found in our scats was collected in the winter (7 out of 10), suggesting the second possibility. The levels of predation on deer by Long Island coyotes is worth monitoring for change over time, as is determining the rates coyotes are directly predating deer versus scavenging roadkill or winter die-off. Additionally, a small population of sika deer (*Cervus nippon*) inhabit Southhaven County Park in Suffolk (far from any of our sites). Once coyotes reach this area, they may begin to predate this non-native species of deer, which are smaller than white-tailed deer.

Regarding vegetation, while coyotes are broadly omnivorous they cannot digest coarse plant matter, and many of the vegetative remains in our scats were of seemingly low nutritional value (e.g. leaves and woody debris). It is unclear if these materials were ingested incidentally or perhaps for dietary but not nutritional needs (e.g. fiber). The ingestion of indigestible plant matter might also occur while a coyote was feeding on nutritional plant material that did not show up in their scat (e.g. incidentally consuming leaves while eating fruits), or may be added to a scat sample after defecation or during collection. Still, vegetation and fruit was common overall in the coyotes we sampled, and this has been the case in many other studies (Murray *et al.* 2015, Watine and Giuliano 2017, Larson *et al.* 2020, Peterson *et al.* 2021, Jensen *et al.* 2022, Reed *et al.* 2023). Fruit, seeds, and mast by themselves were found in > 34% of scats, including ornamental or cultivated fruits such as apple, persimmon, and pear (Table 2). Once again, among-site differences existed, with fruit/seeds being rather uncommon at KPP (most vegetation was leaves or woody debris) and NF (primarily grass).

Growing the seeds extracted from coyote scats allowed us to examine plant items in greater detail. Many of the seeds that we grew turned out to be domesticated fruit species. Persimmons, apples, and pears primarily occurred in GT-UC that has small orchards. Such cultivated species were found in GT-UC and nearby KPP, but were not found at other sites. Identified fruit items in these other sites were primarily grape (which are likely wild since they had seeds), apple (which could be wild crabapples or from orchards), and cherry (likely wild). As commonly thought, coyotes seem to eat whatever food items are most available and easiest to acquire.

Comparison to New York City

The two studies of coyote diet from NYC, Duncan *et al.* (2020) and Henger *et al.* (2022), shared 68 scats in common for their respective analyses. When comparing these 68 samples, Hanger *et al.* (2022) still found important differences between the food items detected between the two studies. Most notably, genetic analysis found greater prevalence of many anthropogenic items, which are often fully digestible and leave little macroscopic remains in scat, leading to a FO_i of 64.2% for anthropogenic items, much higher than Duncan *et al.* (2020; 26.4%) and ours (17.0%). Henger *et al.* (2022) advised that, if implementing both approaches is not possible, the choice of methodology should be based on the question at hand: if the target species' use of anthropogenic foods are a priority then genetic analysis is the better option.

Not surprisingly, the NYC sites sampled by Duncan *et al.* (2020) and Hanger *et al.* (2022) were embedded in a more urbanized landscape, with a percent impervious cover of 49.3% ± 31.7% (mean ± *SD*) in NYC versus a 18.1% ± 23.1% in Long Island. Diversity of food/prey items was higher in NYC than Long Island overall, due to the aforementioned anthropogenic items plus more deer, a few coastal invertebrates, woodchuck (*Marmota monax*), brown rats (*Rattus norvegicus*) and a small number of domestic cats (*Felis cattus*). Diet assemblages of two of the western Nassau sites, GT-UC and HH, were fairly similar to the NYC findings, which aligned with our expectations that the sites closest to NYC and most similar in terms of human population density and urbanization (mean impervious surface of these three sites was 27.4% ± 25.1%, more similar to NYC than the other two sites) would be most similar in diet composition as well. However, KPP was an exception: despite its vicinity to NYC, it not very similar to the findings of Duncan *et al.* (2020) (*CMH* = 0.39) or Henger *et al.* (2022) (*CMH* = 0.48). This dissimilarity was driven by the high prevalence of raccoon, the absence of Crecitidae small mammals, and low anthropogenic items at KPP.

All sites had lower anthropogenic FO_i than NYC, with, again, nearby GT-UC and HH similar to the NYC samples (and KPP surprisingly low). Given the findings of Henger *et al.* (2022), we assume that if a genetic analysis was conducted on our scat sample there would be a greater frequency of anthropogenic items but likely still less than what Henger *et al.* (2022) found in NYC.

Somewhat surprisingly, scats from NYC parks had a greater or similar proportion of white-tailed deer compared to our Long Island sites (Table 2), as we expected deer to be far more prevalent on the landscape and thus in the diets of coyotes in Long Island than in NYC. White-tailed deer resided in only three of the nine NYC parks sampled by Duncan *et al.* (2020) and Henger *et al.* (2022), but apparently in those sites deer are an important food source for coyotes. In all locales, it is unknown whether deer are primarily predated or scavenged as roadkill in either area.

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Ecological implications and future research

Coyotes could potentially have many trophic or other impacts on the ecology of Long Island as they increase in abundance and distribution. Many have hypothesized that urban coyotes could exert top-down trophic limitation of certain over-abundant species, such as white-tailed deer. As discussed above, our data indicate that coyotes in Long Island do eat deer, but probably not at any level that would affect the population dynamics of the species. Another management-related question regarding urban coyotes is how much coyotes tend to prey on free-roaming or feral cats. In the NYC region, cats were present in Duncan *et al.* (2020) and Henger *et al.* (2022) samples within NYC itself (*FOi* = 4.4% and 4.2%, respectively) but none were found in our Long Island sample. As with deer, this is worth monitoring for change over time and against geospatial covariates.

Canada Geese (*Branta canadensis*) are another species that have capitalized on the prevalence of man-made lawns and waterbodies and the lack of predators in urbanized areas, including Long Island. They can thus become very abundant and cause water pollution and other issues. Brown (2007) found that coyotes predated eggs from the nests of Canada Geese in the Chicago Metro Area; geese and impact recreational lawns. We believe Canada Goose made up a portion of the avian remains in our scat (Fig. 3) but are not certain of the magnitude as we could not identify, e.g. fragments of feathers and egg shells, to species level after digestion. While it may seem reasonable to conclude that all or most of the bird remains in our sample were from the few "obvious" more terrestrial species (i.e. Canada Goose and perhaps Wild Turkey (*Meleagris gallopavo*); see Fig. 3), Henger *et al.* (2022) was able to identify a wide variety of avian prey in the coyotes they sampled. Norway rats (*Rattus norvegicus*), the cultural image of "pest species" were present in the two NYC samples but not in our Long Island sample. If coyotes were to eat rats and other rodent undesirable pests it would surely help their public image, but potentially increase their exposure to secondary poisoning.

Competition with other predators is another community-level impact that coyote could potentially have upon the Long Island ecosystem. Henger *et al.* (2022) reported both red fox (*Vulpes vulpes*) and bobcat (*Lynx rufus*) DNA in their NYC sample, though there was only 1 occurrence of each across the 95 scats from urban sites (plus 1 bobcat and 2 red fox in their non-urban scat). Bobcats are not found on Long Island, but red fox are rather common (M. Bottini, unpub data). Coyotes and red fox do compete in northern forests (Gosselink *et al.* 2003), but still co-occur geographically, with red fox often able to avoid the larger coyote by fine-scale spatial partitioning and habitat selection (Mueller *et al.* 2018). As well, Long Island is home to gray fox (*Urocyon cinereoargenteus*), though it is seemingly quite rare (M. Bottini, unpub data). Both urbanization (Parsons *et al.* 2022) and the presence of coyotes and/or red fox (Bauder *et al.* 2020, Allen *et al.* 2022, Morin *et al.* 2022) have been found to negatively affect gray fox–though these patterns are not universal–so the spread of coyotes through Long Island may impact gray fox significantly.

In addition to predation (i.e. top-down) effects such as mesocarnivore suppression, apparent competition, and/or keystone predation, our study also shows that coyotes will likely play a role in seed dispersal. Seeds from coyote scat were readily viable and coyotes may be one of the few mammals that can move between habitat patches through a highly urbanized area.

The breadth of food items, and the variability of diet among sites, speaks to the flexibility of coyotes in making use of whatever food is available. What determines that availability itself is an important avenue of research and involves landscape-level factors (e.g. urbanization, habitat connectivity) and site-level conditions (e.g. land use and management, pollution) on the food and prey base itself. The long-term dynamics of existing prey assemblage and potential coyote impacts on that assemblage offer an array of research questions. This study could not examine diet-covariate relationships beyond descriptive summaries, as we did not have the within-site sample sizes nor the number of independent sites to build complex models. Indeed, there are simply not enough sites with coyotes yet in Nassau and Suffolk to do such an analysis.

Ideally diet studies like this one also incorporate some measures of prey species abundance to compare what species are eaten versus what species are available, though this is made quite difficult by, again, the breadth of coyotes' diets–requiring, to use our results as a guide, a comprehensive mammal survey, songbird and waterfowl surveys, fruit and mast vegetation surveys, and some quantification of available anthropogenic resources. Seasonal patterns likely exist as well, and long-term data on dietary shifts are being collected at GT-UC (S. Perreault, unpub. data).

More precise identification of avian food items is imperative for future research. In this study and others (Morey *et al.* 2007, Poessel *et al.* 2017, Watine and Giuliano 2017), birds were grouped into a single category, likely assuming, as we did, that avian prey would be a minor component of coyotes' diet. Here, GT-UC and FI had the highest avian frequencies, and we did photograph coyotes carrying both Canada Geese and Northern Bobwhite (*Colinus virginianus*) at GT-UC. But these incidental observations shed little light on what portions these species make up in the diet nor whether other birds or their eggs are consumed. Henger *et al.* (2022) showed a wide diversity of avian prey when genetic methods were used. FI had a relatively high frequency of avian items as well, and the more coastal and open habitat there may provide vastly different avian prey opportunities (e.g. shore- or wading birds). Additionally, in more exurban or rural areas of Long Island, the degree to which coyotes might feed on chickens, often kept by residents, is an important management question to explore.

Likely the most important diet-related questions are whether and where coyotes might be preying on domestic and livestock species, what factors might lead to such behavior, and how managers can prevent or reverse these occurrences when they arise. It appears that, for the moment, coyotes on Long Island have broad, omnivorous diets–as is generally the case across the species' range (Hayward *et al.* 2023) – only rarely make use of anthropogenic leftovers, and, based on our samples, are not eating domestic animals with any frequency.

The degree to which a species, such as the coyote, can alter its diet to make use of the resources that are available to it is an important factor in whether a species can adapt to urban, suburban, and agricultural landscapes. There are many remaining areas of Long Island that we expect coyotes to colonize in the near future that include coastal and freshwater wetlands, pine barrens, beach dunes, shrublands, and large meadows, along with developed residential areas. The flexibility that coyotes and other predators might (or might not) exhibit across all of these habitats, within the wide spectrum of human development also found there, is an important topic for urban wildlife ecologists. Lastly, we detected a variety of small mammals and other species that themselves have been able to adapt to this urbanized landscape, and have ecological dynamics and value apart from feeding coyotes. Open space in highly altered and developed

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landscapes can still support populations of native wildlife, many of which can now support a top predator, and, in turn, maintain a meaningful level of trophic function. Conserving and increasing natural areas, even in the most urbanized regions of the world, can be essential for species viability and ecosystem function.

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Author contributions

Christopher Nagy (Conceptualization [supporting], Formal analysis [equal], Writing—original draft [lead], Writing—review & editing [lead]), Neil Duncan (Data curation [equal], Formal analysis [equal], Investigation [equal], Methodology [equal], Resources [equal], Writing—review & editing [equal]), Stephane V Perrault (Conceptualization [equal], Data curation [equal], Formal analysis [equal], Funding acquisition [equal], Investigation [equal], Methodology [equal], Project administration [equal], Resources [equal], Writing—review & editing [equal]), Michael Bottini (Conceptualization [equal], Data curation [equal], Investigation [equal], Methodology [equal], Resources [equal], Writing—review & editing [equal]), Lisa Filippi (Conceptualization [equal], Data curation [equal], Funding acquisition [equal], Investigation [equal], Methodology [equal], Resources [equal], Writing—review & editing [equal]), and Jennifer Murray (Investigation [equal], Resources [equal]), Russell L Burke (Conceptualization [equal], Data curation [equal], Funding acquisition [equal], Investigation [equal], Methodology [equal], Project administration [equal], Resources [equal], Supervision [equal], Validation [equal], Visualization [equal], Writing—review & editing [equal])

Supplementary material

Supplementary material is available at *JUECOL* online.

Conflicts of interest

None declared.

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Data availability

Data are available in Supplementary Data file.

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