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Dietary habits of fishing cats in a human-dominated wetland in Coastal Thailand

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Abstract. *Wongson T, Khaewphakdee S, Mongkonsin W, Serieys LEK, Wong W-M, Yindee M, Pattanarangsan R, Suksavate W, Promkuntod P, Klakhaeng C, Sukmasuang R. 2024. Dietary habits of fishing cats in a human-dominated wetland in Coastal Thailand. Biodiversitas 25: 2788-2797.* Fishing cats, intimately connected to wetland habitats, face an escalating threat from human activities and environmental change. With its significant findings, this study offers a comprehensive insight into the dietary habits of fishing cats in a human-dominated wetland in coastal Thailand. By examining the scats of 192 fishing cats (*Prionailurus viverrinus* Bennett 1833) and the remains of 328 prey items, we detailed the fishing cat's diet and assessed its seasonality. Consequently, we identified 16 prey species consumed by fishing cats during the study period. The primary prey was fish, followed by rodents, birds, Indo-Chinese rat snakes (*Ptyas korros* (Hermann Schlegel 1837)), insects, crabs, and snails. The most crucial prey was the climbing perch (*Anabas testudineus* Bloch 1792) (n=69), followed by bandicoot rats (Bandicota indica Bechstein, 1800) (n=54), domestic chicken (*Gallus gallus* Linnaeus 1758) (n=48), and snakehead murrel (*Channa striata* Bloch 1793) (n=38). The niche breadth index indicated the highest specialization during the summer, while the dietary diversity index was 0.44, 0.52, and 0.38 during the summer, rainy, and winter seasons, respectively. Seasonal variations in dietary composition were not statistically significant. The niche overlap index was 0.95 between the summer and the rainy season, 0.91 between the rainy season and winter, and 0.87 between the summer and winter. These findings, with their direct implications for the conservation of fishing cats, highlight the urgent need for effective land-use management in species preservation.

Keywords: Dietary diversity, foraging ecology, niche breadth, prey composition, scat analysis

INTRODUCTION

Dietary items are crucial in determining several life history traits of apex predators to understand predator ecology and prey-predator dynamics in an ecosystem; dietary information is essential (Schmitz 2017). Therefore, dietary knowledge is crucial to comprehending prey-predator dynamics and predator ecology in an ecosystem (Malla et al. 2023). The fishing cat, a small wild feline, is a wetland specialist that inhabits wetlands, mangroves, rivers, and swamps across South and Southeast Asia (Malla et al. 2023). It prefers lowland areas and grows well in marshy areas, oxbow lakes, reed beds, tidal creeks, and mangrove zones (Mishra et al. 2022). The species has been classified as globally vulnerable since 2016 by the IUCN (2016) owing to significant population decline, particularly in Southeast Asia (Mukherjee 2016); this species faces threats from habitat loss and degradation (Rana et al. 2022). There have been limited efforts to comprehensively assess the current status of fishing cats that widespread land-use changes pose to fishing cats (Thaung et al. 2018; Kolipaka et al. 2019; Phosri et al. 2021; Mishra et al. 2022; Malla et al. 2023). There are few additional studies on the dietary patterns of fishing cats (Cutter 2015; Malla et al. 2023).

Wetlands are crucial ecosystems of this species that play a key role in supporting biodiversity and providing various ecosystem services (Liao et al. 2020; Alikhani et al. 2021). Many different types of plants and animals, including migratory and endangered species, depend on these special habitats for survival. The rapid conversion of wetlands has severe consequences for native species inhabiting them (Parvez and Mohsin 2022), disrupting vital breeding grounds, foraging areas, and habitats crucial for countless plant and animal species (Kuijper et al. 2023). Additionally, alterations in hydrological regimes and water quality further threaten the survival of these species and the overall health of wetland ecosystems (Zhu et al. 2023). Recognizing the profound impact of land conversion on native wetland species is crucial for effective conservation efforts to preserve biodiversity and safeguard the ecological integrity of these invaluable habitats (Maltby 2022). Like other wetlands, the wetlands around Khao Sam Roi Yot National Park (KSRYNP) have been under constant threat for over 40 years. These threats include the conversion of natural wetlands into agricultural areas, aquaculture, and community settlements. Such transformations directly impact the area and the fishing cat population (Phosri et al. 2021).

Thus, there is an urgent need for more information to evaluate the ecological impact of human activities on fishing cats (Eva et al. 2022). It is particularly crucial to understand how changes in land use affect dietary patterns, especially in wetland landscapes undergoing profound and rapid changes due to anthropogenic activity (Dou et al. 2023). The survival of fishing cats depends on effective co-management strategies involving both humans and the conservation of wild species in these dynamic landscapes (Chapron et al. 2014; Ali et al. 2018; Phosri et al. 2021). This species' major national strongholds are the KSRYNP and the surrounding habitats (Chutipong et al. 2019).

Therefore, studying the species' diet in disturbed habitats is important to understand the relationship between this species and human activities in fragile areas for conservation management. Especially along park boundaries used for freshwater fish farming, some parts of the Khao Sam Roi Yot Wetland (KSRYWL) have been transformed into human settlements and commercial aquaculture operations during the last 40 years (Phosri et al. 2021).

We investigated the dietary items of fishing cats in human-modified habitats around the KSRYNP area, Prachuap Khiri Khan, in coastal Thailand. We tested the following two hypotheses. First, we hypothesized that in this human-dominated landscape, natural fish remains the primary food source for the fishing cats in the human-dominated landscape. In contrast, other food sources may be linked to human settlements. Second, we hypothesized that the composition of the fishing cat diet varies seasonally in this area. The findings of this study provide valuable insights into the feeding ecology of fishing cats in human-dominated landscapes, informing future conservation and management strategies for these intricate landscapes. This information is particularly pertinent for managing habitats that overlap with areas of human activity and the habitats of this unique and rare wild species.

MATERIALS AND METHODS

Ethics statement

This study was conducted under the permission of the Department of National Parks, Wildlife and Plant Conservation (DNP) (License No. 0909.204/10153, dated 20 May 2022) as part of the project on the ecology of fishing cats using radio satellite collar in the area surrounding KSRYNP. Additionally, the study was approved by the Office of the National Research Council (Permission Document No. 0401/9980, dated 7 June 2022). The researchers also hold a certificate for completing animal rights training in experimental work from the Office of the National Research Council, Thailand.

Study site

The study area comprises the KSRYNP (12°11'N, 100°01'E), harbors diverse wetland and forest ecosystems (e.g., limestone ridge mountains that are a part of the Tenasserim Range, as well as salt pans, farmed areas, mudflats, grassland and shrubs, mangrove forests, and sandy beaches (DNP 2015). Large freshwater marshes (37 km^2) are also present; of these, about 18 km^2 were designated as Ramsar wetland sites in 2008 (RSIS 2015) (Figure 1). It has a tropical monsoon climate with an average of 800-1,200 mm annual rainfall. At least 292 plant species in 233 genera and 92 families, including 174 aquatic plant species and 64 wetland species related to coastal, estuarine, and marine habitats, make up freshwater marshes, which are hotspots for biodiversity (RSIS 2015).

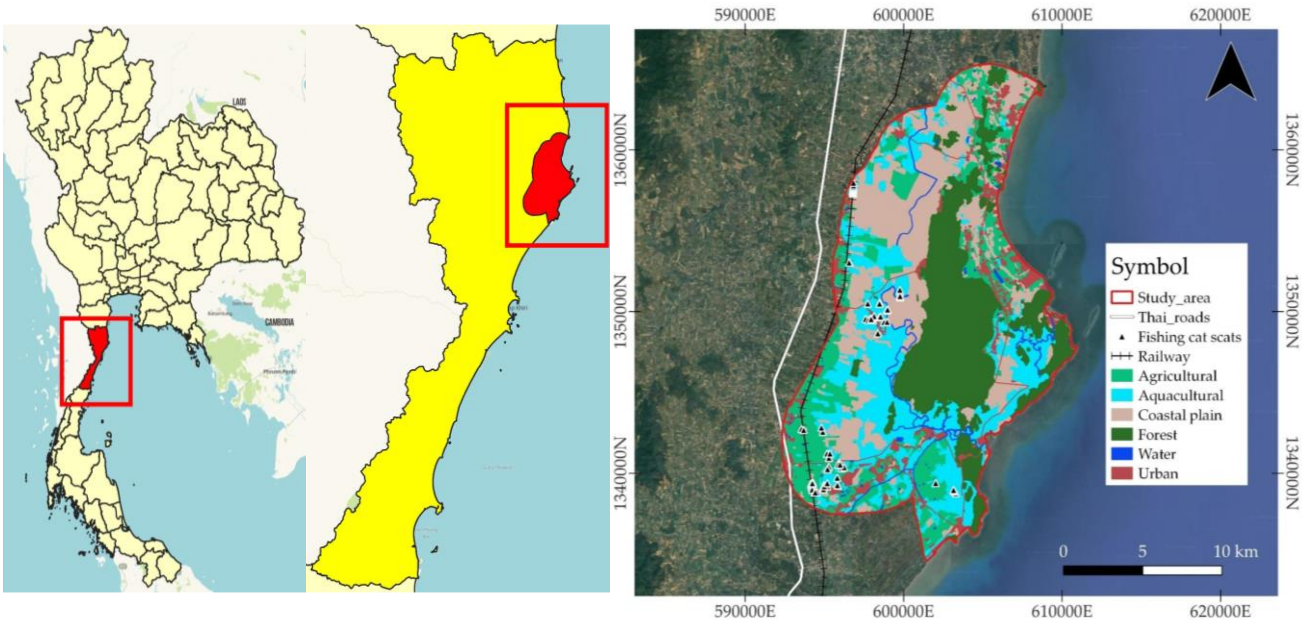

Figure 1. Map of the study area showing locations of the Khao Sam Roi Yot Wetland (KSRYWL), Thailand and the fishing-cat scat collection points

Their native vegetation such as sakae naa (*Combretum quadrangulare* Kurz), portia tree (*Thespesia populnea* (L.) Sol. ex Corrêa), dragon blood tree (*Dracaena cochinchinensis* (Lour.) S.C.Chen), invasive vegetation such as narrow leaf cattail (*Typha angustifolia* L.), herbaceous seepweed (*Suaeda maritima* (L.) Dumort.), needle bush (*Acacia farnesiana* (L.) Willd) and cash crops such as pineapple (*Ananas comosus* (L.) Merr.), coconut tree (*Cocos nucifera* L.), and rice (*Oryza sativa* L.) (Johnson et al. 2016). Regarding wildlife diversity, marshes support at least 316 bird species, including terrestrial and water birds (Greenberg et al. 2014; DNP 2015), and at least 41 freshwater fish species across 35 genera and 20 families (RSIS 2015). The DNP (2015) classified the climatic conditions in KSRYWL into three seasons. The summer season ranges from March to June (range 41-95 mm. rainfall/month), the rainy season ranges from July to November (range 89-226 mm. rainfall/month), and the winter season ranges from December to February (range 35-55 mm. rainfalls/month) (Thai Meteorological Department Automatic Weather System 2023).

Scat collection and analysis

Scats were sampled opportunistically (Manning et al. 2022) around or at the edges of active and abandoned ponds, urban areas, coastal plains, and some parts of the natural forest areas adjacent to mangroves or human walking trails that covered the entire core zone, especially in the western part of the wetland where fishing cat signs were found and reported based on camera trap surveys and movement of the twelve fishing cats via radio satellite collar monitoring. Scat collection was done while working with camera traps, satellite telemetry monitoring during ground check in the field (Jansen et al. 2019), 2 times per day, and occupancy surveys (Seidlitz et al. 2019) to ensure that the scats collected truly belong to the fishing cat. Scat collection occurred during the period from August 2022 to July 2023. In the study area, although domestic cats were found, however, it is possible to distinguish between domestic cats and fishing cat droppings because they differ greatly in size and shape, and area found. Fishing cat droppings are often found at latrine sites with multiple scats, most likely from the same individual. Since the fishing cat's scats were found in the same area simultaneously, only one scat was selected to avoid sample bias. According to Malla et al. (2023), their size and shape recognized the scats and oblique indicators like scrape marks and pug marks. The scats collection was done with the following assumption: the scats gathered from the study area were thought to be randomly distributed. Every scat was tracked by GPS location and date, and they were all kept apart in plastic bags.

The Department of Forest Biology at Kasetsart University and the Wildlife Research Group laboratories of the Department of National Parks and Wildlife Conservation were used for scat analysis (Souza and Azevedo 2021) to ascertain the diets of the fishing cats. Some dried scats were soaked in water and passed through a metal sieve (1.5 mm mesh size) after each was individually cleaned with water (Charaspet et al. 2020; Kamler et al. 2020). Only undigested prey remains, predominantly hair and bone fragments, were used to identify prey species (Desai et al. 2021). The lowest possible taxonomic level was used to identify and separate all non-digested prey remains found in the scat, including hairs, feathers, crab exoskeletons, fish otoliths, fish scales, insect parts, and plant materials (Malla et al. 2023). Specifically, the bones, teeth, jawbones, hair, and feathers found in each scat were classified into taxa and identified at the species level by microscopic comparison of prey items with a reference collection obtained from the study sites (Lee et al. 2014). Hair samples were then used to prepare medullar and cuticular slides, which were compared with reference slides and images (Charaspet et al. 2020). The morphology and otolith composition of fish were used to identify species (Malla et al. 2023) with the help of a reference set gathered from local and field markets. The catfish in the study area were identified by their otoliths and dorsal and pectoral fin spines because they lacked scales on their bodies (Malla et al. 2023). According to Kale and Kumar (2021), the feathers found in the scats were used to identify the birds. The vertebral column bones and scales found in the scats were used to identify the species of snakes (Vasmatkar et al. 2020). The genus, family, or order level was used to identify items that could not be identified at the species level.

Data analysis

We used the Shannon diversity index (Konopiński 2020) to estimate the diversity of the fishing cat diet, and we used the Estimate Software (Colwell 2014) to reorder the scat samples in their original order. After that, we evaluated dietary diversity concerning sample size to see if it was sufficient to characterize fishing cats' seasonal diet.

Percent occurrence (PO) and frequency of occurrence (FO)

Diet quantification was based on percentage occurrence (PO), which is the number of times a specific item was found as a percentage of all items found, and frequency of occurrence (FO), which is the proportion of total scats in which an item was found (Parsons et al. 2019).

Niche breadth index

Based on Levin's standardized niche breadth index (Sá-Oliveira et al. 2014), the niche breadth of each species was assessed. By applying the following measure, which was suggested by von Meijenfeldt et al. (2023), the index was standardized on a scale from zero to one according to the following equation:

$$B_s = \frac{\frac{1}{\sum p_{i,s}^2} - 1}{\mathrm{n} - 1}$$

Where:

$p_{i,s}$: the percentage of species s individuals found in niche

i, n : the total number of available niches, and s is the focal species

Using a scoring system ranging from zero to one, where zero represents an extreme specialist, and one represents an extreme generalist, this index adapts the original Levin niche breadth index.

Dietary diversity index

We measured dietary diversity using raw data by calculating the dietary diversity index (Zhao et al. 2017) in the scats according to the following equation:

$$H_b = \frac{\ln(Ni) - \sum \ln ni}{Ni}$$

Where:

N : the number of prey species in all recorded samples

n_i : the number of distinct prey categories in category i

H_b: the prey diversity in the scats.

Diet breadth and overlap indices were evaluated using the primary prey categories. The sample season groups were summer (March-June), winter (December-February), and rainy season (July-October). Levin's standardized index of food niche breadth (Bobadilla et al. 2022) was used to measure the seasonal trophic niche breadth.

Prey overlap index

The Pianka index (Tsafack et al. 2021) computed the dietary overlap among the three distinct seasons.

$$O_{jk} = \frac{\sum_n^i P_{ij} P_{ik}}{\sqrt{\sum_n^i P_{ij}^2 \sum_k^n P_{ik}^2}}$$

Where:

n : the total number of items

P_{ij} : the proportion of the ith resource in the diet of species j

P_{ik} : the proportion of the ith resource in the diet of species k

O_{jk} : Pianka's index of niche overlap between species j and k. The Pianka index values were categorized using Sa-Oliveira et al. (2014) and Bosenbecker and Bugoni (2020), which adhere to the Levins index's bounds. Pianka's index is classified as (i) extremely high ($0.90 \geq O_{jk}$); (ii) high ($0.90 > O_{jk} \geq 0.70$); (iii) moderate ($0.70 > O_{jk} \geq 0.50$), and (iv) low ($0.50 > O_{jk}$). The index ranges from 0 (no overlap) to 1 (complete overlap).

Various aspects of the analysis were conducted to understand the potential variations in food items. We employed chi-square contingency tables and Fisher's exact test to assess significant differences among individual prey types across seasons. Therefore, we calculated the Shannon-Wiener (H_0) index to examine seasonal diet diversity.

RESULTS AND DISCUSSION

The summer (n=64), rainy season (n=76), and winter (n=52) saw the sampling of 192 fishing cat scats, and the summer (n=114), rainy season (n=130), and winter (n=84) saw the sampling of 328 distinct prey items from scats of the identified fishing cats. There were included multiple copies of the same item. The data presented in Figure 2 indicates that the sampling effort was adequate to estimate the dietary patterns of the fishing cats in the study area, as evidenced by the accumulative curve plotted against total scats and showing an asymptote of roughly >30 samples.

Prey composition

A total of 328 prey items were identified in fishing cat scats. Among the scats, 49.0% contained one prey item, 35.4% contained two prey items, and 15.6% contained more than three prey items. A total of 16 prey species, including four fish species, three species of rodents, birds, and insects, and one species each of reptiles, crabs, and snails, covering a total of seven taxa of prey items, were classified. Every taxon was identified down to the genus or species level. According to the occurrence percentage found in 161 scats (PO=48.9%), fish constituted a significant portion of the diet of fishing cats in the study area. The fish found in the scats were divided into four species: climbing perch (FO= 35.9%; PO= 21.5%), snakehead murrel (FO=19.8%; PO=11.8%), and Nile tilapia (*Oreochromis niloticus* Linnaeus 1758) (FO=18.7%; PO=10.0%) being the most commonly detected. Catfish (*Clarias macrocephalus* Günther 1864) accounted for 18 scats (PO=5.6%), according to our observations made using otoliths and fin spines.

The second most frequent prey found by the scats was rodents. Remains of rodents were found in 82 scats (PO=25.5%) representing three species, with bandicoot rats (FO=28.1%, PO=16.8%), Northern treeshrew (*Tupaia belangeri* Wagner 1841) (FO=1.6%; PO=0.9%), and roof rats (*Rattus rattus* Linnaeus 1758) (FO=13.0%; PO=7.8%) being the most important. There were bird remains in 62 scats (PO=19.3%), making birds the third most important dietary component. We classified three bird species as among the main prey of fishing cats, such as domestic chicken (FO=25.0%; PO=14.9%), White-breasted waterhen (*Amaurornis phoenicurus* Pennant 1769) (FO=4.7%; PO=2.8%), and Lesser whistling-duck (*Dendrocygna javanica* Horsfield 1821) (FO=2.6%; PO=1.6%). We also detected Indo-Chinese rat snake (FO=4.7%; PO=2.8%), crab (FO=2.1%; PO=0.9%), snail (FO=2.1%; PO=0.9%), and insects (FO=2.1%; PO=1.2%) as minor prey items. Details are presented in Tables 1-4.

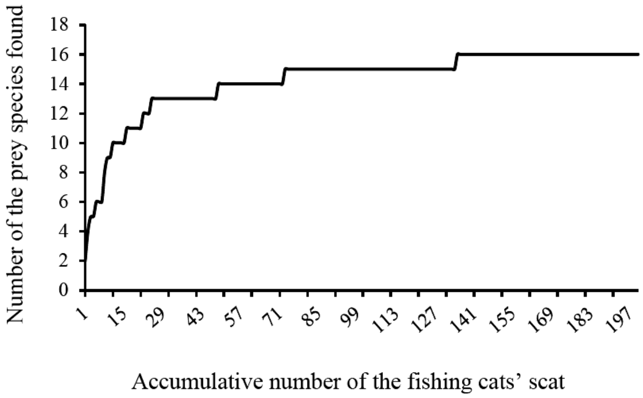

Figure 2. An asymptote of roughly >30 samples was observed when the number of the prey species found was plotted against the accumulative number of the scats

Table 1. The prey composition of the fishing cat, as determined by 192 scat samples collected from August 2022 to July 2023, revealed the frequency, percentage, and number of times a prey category was found in the KSRYNP study area, broken down by season

Prey categories	Summer			Rainy			Winter			Total		
	n	PO	FO	n	PO	FO	n	PO	FO	n	PO	FO
Fishes	60	54.5	93.7	61	46.9	80.2	40	49.4	76.9	161	48.9	83.9
Rodents	24	21.8	30.0	36	27.7	47.3	22	27.2	42.3	82	25.5	42.7
Birds	21	19.1	32.8	25	19.2	32.9	16	19.8	25.1	62	19.3	32.3
Snake	3	2.7	4.7	3	2.3	3.9	3	3.7	5.8	9	2.8	4.7
Crab	1	0.9	1.6	2	1.5	2.6	1	1.2	1.9	4	0.9	2.1
Snail	1	0.9	1.6	2	1.5	2.6	1	1.2	1.9	4	0.9	2.1
Insects	3	2.7	4.7	1	1.8	1.3	0	0.0	0.0	4	1.2	2.1
Other Arthropod	1	0.9	1.6	0	0.0	0.0	1	1.2	1.9	4	0.3	0.5

Table 2. Prey composition of the fishing cat in the KSRYNP, separated by season based on 192 scat samples collected between August 2022 to July 2023, showed the number of prey species found

Prey items		No. of prey found by season (number of scat samples in parenthesis)			Total (192)
		Summer (64)	Rainy (76)	Winter (52)	
Fishes	Climbing perch (*Anabas testudineus*)	20	28	21	69
	Snakehead murrel (*Channa striata*)	15	17	6	38
	Nile tilapia (*Oreochromis niloticus*)	19	10	7	36
	Catfish (*Clarias* spp.)	6	6	6	18
	Subtotal fishes	60	61	40	161
Rodents	Bandicoot rat (*Bandicota indica*)	15	20	19	54
	Roof rat (*Rattus rattus*)	9	13	3	25
	Northern treeshrew (*Tupaia belangeri*)	0	3	0	3
	Subtotal rodents	24	36	22	82
Birds	Domestic chicken (*Gallus gallus*)	19	21	8	48
	White-breasted waterhen (*Amaurornis phoenicurus*)	2	1	6	9
	Lesser whistling-duck (*Dendrocygna javanica*)	0	3	2	5
	Subtotal birds	21	25	16	62
Snake	Indo-Chinese rat snake (*Ptyas korros*)	3	3	3	9
Crab	Mangrove crab (*Sesarma mederi*)	1	2	1	4
Snail	*Sermyla riquetii*	1	2	1	4
Insects	Harvesting ant (*Carebara* spp.)	2	0	0	2
	Mealworm (*Alphitobius* spp.)	1	1	0	2
	Subtotal insects	3	1	0	4
Other arthropod	Millipede (*Cylindroiulus* spp.)	1	0	1	2
	Total number of preys found	114	130	84	328

Table 3. Prey items of the fishing cat in the KSRYNP, separated by season based on 192 scat samples collected between August 2022 to July 2023, showed the percentage of occurrence (PO) of prey species found

Prey items		%PO (number of prey item in parenthesis)			%Total of PO (n=328)
		summer (n=114)	Rainy (n=130)	Winter (n=84)	
Fish	Climbing perch (*Anabas testudineus*)	18.2	21.5	25.9	21.5
	Snakehead murrel (*Channa striata*)	13.6	13.1	7.4	11.8
	Nile tilapia (*Oreochromis niloticus*)	17.3	7.7	8.6	10.0
	Catfish (*Clarias* spp.)	5.45	4.6	7.4	5.6
	Subtotal fishes	54.5	46.9	49.4	48.9
Rodents	Bandicoot rat (*Bandicota indica*)	13.6	15.4	23.5	16.8
	Roof rat (*Rattus rattus*)	8.2	10.0	3.7	7.8
	Northern treeshrew (*Tupaia belangeri*)	0.0	2.31	0.0	0.9
	Subtotal rodents	21.8	27.7	27.2	25.5
Birds	Domestic chicken (*Gallus gallus*)	17.3	16.1	9.9	14.9
	White-breasted waterhen (*Amaurornis phoenicurus*)	1.8	0.8	7.4	2.8
	Lesser whistling-duck (*Dendrocygna javanica*)	0.00	2.3	2.5	1.6
	Subtotal birds	19.1	19.2	19.8	19.3
Snake	Indo-Chinese rat snake (*Ptyas korros*)	2.7	2.3	3.7	2.8
Crab	Mangrove crab (*Sesarma mederi*)	0.9	1.5	1.2	0.9
Snail	Snail (*Sermyla riquetii*)	0.9	1.5	1.2	0.9
Insects	Harvesting ant (*Carebara* spp.)	1.8	1.0	0.0	0.6
	Mealworm (*Alphitobius* spp.)	0.9	0.8	0.0	0.6
	Subtotal insectes	2.7	1.8	0.0	1.2
Other arthropod	Millipede (*Cylindroiulus* spp.)	0.9	0.0	1.2	0.3

Seasonal variation in the diet

Table 1 shows that fish consistently constituted the primary prey of fishing cats across all three seasons, followed by rodents, birds, and Indo-Chinese rat snakes. In the case of birds, the percentage occurrence and the % frequency of occurrence were somewhat consistent across seasons. Conversely, prey species like crabs, snails, and insects are opportunistically consumed.

Levins'' standardized niche breadth index was the highest during the rainy season (0.39) compared to the summer and winter seasons (0.32 and 0.37 respectively). There were no significant differences across seasons, indicating that they were generalists. Based on the percentage of occurrence of 48.9% (Table 1) of fish taxa, the fishing cat was a fish specialist, especially during the summer season. For the dietary diversity index, the results were 0.40, 0.34, and 0.47 during the summer, rainy, and winter seasons, respectively (Table 5).

Comparisons between seasons of the composition of the fishing cat diet showed no significant differences in any pairs. There was a high degree of niche overlap between the summer and the rainy season, as evidenced by the Pianka overlap index between summer and the rainy season (0.98), which showed extremely high overlap, and between summer and winter (0.87) and rainy and winter (0.91) (Table 6).

Table 4. Prey items of the fishing cat in the KSRYNP, separated by season based on 192 scat samples collected between August 2022 to July 2023, showed % frequency of occurrence (%FO) of prey species found

Prey items		%FO (number of scat samples in parenthesis)			%Total of FO (n=192)
		Summer (n=64)	Rainy (n=76)	Winter (n=52)	
Fish	Climbing perch (*Anabas testudineus*)	31.2	36.8	40.38	35.9
	Snakehead murrel (*Channa striata*)	23.4	22.4	11.53	19.8
	Nile tilapia (*Oreochromis niloticus*)	29.7	13.1	13.46	18.7
	Catfish (*Clarias* spp.)	9.4	7.9	11.53	9.4
	Subtotal fishes	93.7	80.2	76.9	83.8
Rodents	Bandicoot rat (*Bandicota indica*)	15.9	26.3	36.5	28.1
	Roof rat (*Rattus rattus*)	14.1	17.1	5.8	13.0
	Northern treeshrew (*Tupaia belangeri*)	0	3.9	0	1.6
	Subtotal rodents	30.0	47.3	42.3	42.7
Birds	Domestic chicken (*Gallus gallus*)	29.68	27.6	9.7	25.0
	White-breasted waterhen (*Amaurornis phoenicurus*)	3.12	1.3	11.5	4.7
	Lesser whistling-duck (*Dendrocygna javanica*)	0	3.9	3.8	2.6
	Subtotal birds	32.8	32.9	25.1	32.3
Snake	Indo-Chinese rat snake (*Ptyas korros*)	4.7	3.9	5.8	4.7
Crab	Mangrove crab (*Sesarma mederi*)	1.6	2.6	1.9	2.1
Snail	Snail (*Sermyla riquetii*)	1.6	2.6	1.9	2.1
Insects	Harvesting ant (*Carebara* spp.)	3.1	0	0	1.0
	Mealworm (*Alphitobius* spp.)	1.6	1.3	0	1.0
	Subtotal insects	4.7	1.3	0	2.1
Other Arthropod	Millipede (*Cylindroiulus* spp.)	1.6	0	1.9	0.5

Table 5. Levins'' standardized niche breadth and dietary diversity index in dietary items of the fishing cat in summer, rainy, and winter seasons

	Summer	Rainy	Winter	Overall
Niche breadth index	0.32	0.39	0.37	0.88
Dietary diversity index	0.40	0.34	0.47	0.17

Table 6. Utilizing Fisher's exact tests and the niche overlap index, also known as the Pianka index, different seasons can be used to compare the diet composition and dietary diversity of fishing cats

	Diet composition			Dietary diversity			Pianka index
	χ^2	df	*P*	t	df	P	
Summer vs. Rainy	4.19	6	0.65	0.16	245	0.86	0.98
Summer vs. Winter	2.06	6	0.91	0.06	178	0.94	0.87
Rainy vs. Winter	0.52	6	0.99	0.14	178	0.18	0.91

Discussion

We used a classical, non-invasive approach to dietary assessment by analyzing the contents of fishing cat scats opportunistically found in the study area. Scats were primarily collected from the human-dominated section of our study area, suggesting that fishing cats predominantly prey on fish species within human-dominated landscapes.

A minimum of 16 distinct prey species, encompassing seven major taxa, were identified. These included fishes, rodents, birds, crabs, snakes, snails, and insects. Fish were the dominant prey items detected, particularly two native species: climbing perch and snakehead murrel. These findings are consistent with previous studies on fishing cats, both in this area (Cutter 2015) and in the Godavari Delta in Andhra Pradesh, India (Malla et al. 2023), where aquatic prey dominated their diet. In general, carnivores exhibit hunting behavior influenced by prey availability, aligning with the principles of the optimum foraging theory (Ganguly and Adhya 2022). Climbing perch, the principal food item identified in scats, is abundant in these areas, which may explain why they were the most common prey items in the study area. This suggests that water bodies within a human-dominated landscape provide ample prey for fishing cats. However, fishing cats also prey on cultivated catfish, demonstrating that they might target fish in aquaculture ponds (Phosri et al. 2021). In India, fishing cats target cultivated carp; as a result, farmers will leave fish laced with poison at pond edges to target fishing cats (Adhya et al. 2022). Although they are targeted for killing chickens, which we have verified are part of the diet of fishing cats in our study area, fishing cats are not, as far as we know, persecuted for consuming cultivated catfish.

The overall niche breadth index (0.88) suggests that fishing cats exhibit a high level of generalization, supplementing their aquatic diet with terrestrial species. Indeed, the fishing cat diet also comprised native bandicoot rats and, to a lesser degree, roof rats. Similarly, a previous study on caracals in an urban area demonstrated that they were found to largely prey on native species, with the consumption of domestic and commensal animals comprising a small proportion of their diet (Leighton et al. 2020). However, bandicoot rats thrive in disturbed landscapes, including built-up and agricultural areas (Lin et al. 2023), and thus are likely to be common animals in such landscapes.

Although fishing cats have been reported to feed on waterfowl such as coots, ducks, and shorebirds (Malla et al. 2023), the diet of the fishing cats in our study area included very few native bird species, despite the KSRYWL area being a crucial for resident and migratory bird habitat, with over 316 bird species reported (Greenberg et al. 2014; DNP 2015). Our study area's fishing cats may have eaten a limited number of native bird species, which two factors could explain. First, within the study area, many water bodies are utilized as cultivated shrimp or fish ponds with extensive netting around the edges and tops of the ponds to prevent birds from preying on the cultivated species. Notably, only lesser whistling ducks (*Dendrocygna javanica* Horsfield 1821) with a migratory status were observed as fishing cat prey during winter, albeit in small numbers (n=2). White-breasted waterhen (*Amaurornis phoenicurus* Pennant 1769), a resident bird (Sarkar 2024), constituted a large portion of the diet of fishing cats (n=6), indicating that fishing cats are opportunistic predators that prey on what is found in the landscape. The feathers of domestic chickens have large bases, completely different from the small feathers of bird species. Birds preyed upon by fishing cats include White-breasted waterhen and lesser whistling ducks. Therefore, in addition to the size of the feather bases, the color of domestic chicken feathers is also black, while birds' feathers are light-colored or white. This difference in feather color can be used to distinguish them. These findings underscore that despite being in a human-modified landscape, the diet mostly depended on native prey species. Overall, the study's results showed that the composition of prey species did not significantly change between seasons.

Conservation and management implications

The findings of this study indicate that the primary prey of fishing cats remain natural fish species, such as climbing perch and snakehead murrel, with Nile tilapia, an invasive species, also being consumed. Some fish, such as climbing perch, snakehead murrel, and Nile tilapia, are from farmed sources, particularly in abandoned ponds, where fishing cats depend heavily on aquatic life to survive and thrive. While sea bass and shrimp, commonly farmed species, were absent from the diet, catfish remains were found in scats, albeit in lower proportions than other prey fish, such as climbing perch and snakehead murrel. These findings underscore the importance of managing abandoned fishpond areas to ensure they serve as safe habitats and crucial food sources for fishing cats in the region. Furthermore, legal measures such as land tax regulations can be employed to compensate citizens who refrain from expanding or developing ponds in wetland areas.

This study also revealed that domestic chickens constitute a significant portion of the fishing cat diet, likely leading them to frequent community areas and posing potential threats to the fishing cat population resulting from the retaliatory killing of fishing cats. The main reason for the direct killing of fishing cats may be that locals believe they prey on their cattle, fisheries, and poultry (Chowdhury et al. 2015). Therefore, livestock and poultry management practices should be publicized and implemented, incorporating compensation schemes and protective measures to deter fishing cats from entering human settlements. Creating barriers in fishponds to restrict fishing cat movement, increasing community knowledge, and offering compensation for the fish lost to fishing cats to lessen confrontation with communities and prevent potential reprisals have been recommended as measures for this (Mishra et al. 2021).

Therefore, close monitoring and extensive research to mitigate potential risks is vital. Additionally, the discovery of microplastics in fishing cat droppings in the study area (Wongson et al. 2023). Based on the analysis of 32 fishing cat scat samples collected in the area, microplastics were found in 10 samples (31.25%). A total of 32 microplastics were detected; of these, 20 pieces (62.5%) had diameters greater than 5 millimeters, 10 pieces (31.25%) had diameters between 1 and 5 millimeters, and 2 pieces (6.25%) had diameters less than 1 millimeter (Wongson et al. 2023). Wongson et al. (2023) underscore the silent yet formidable threat to their survival, particularly in areas heavily impacted by human activities (Ratnayaka et al. 2023). As a result, the conservation of protected areas under natural conditions is paramount, as these areas will serve as a critical stronghold for fishing cat populations in the future. There should be initiatives to educate people about the value of wetlands and the pressing need to protect the natural habitats of uncommon and endangered animals. This information, including ethical considerations in animal treatment, should be widely disseminated, particularly among the youth. Collaborative efforts with local communities are essential to reinforce management strategies and implement effective conservation measures (Chapron et al. 2014; Ali et al. 2018; Phosri et al. 2021). Adhya et al. (2022) stated that the fishing cat can serve as a flagship species to help conserve rapidly degrading low-altitude wetlands and their ecological communities in the major South and Southeast Asian river basins. She emphasized that such conservation efforts must be socio-ecologically sensitive, include multiple stakeholders, and operate within a framework of wise-use principles.

In the case of studies on fecal analysis for dietary investigations of wildlife using DNA barcoding have been reported in several carnivorous species, such as the leopard cat (*Prionailurus bengalensis* Kerr 1792) (Xiong et al. 2016; Kim et al. 2018), the Eurasian otter (*Lutra lutra* Linnaeus 1758) (Kumari et al. 2019; Wang et al. 2022), and the raccoon dog (*Nyctereutes procyonoides* Gray 1834) (Woo et al. 2022). This technique has also been used to study diet diversity in ungulate species (McShea et al. 2019). However, the study of dietary diversity in some carnivorous wild animals has often been conducted without mention of DNA analysis, such as studies on the diet of the fishing cat in wetlands (Ratnayaka et al. 2023; Harika et al. 2023). The scat collection was conducted assuming no other wild cat species were in the area, which was confirmed by installing camera traps in the locations where fishing cat latrines were found. During the ground check, the locations were based on 12 satellite-radio collar fishing cats 2 times per day to ensure that the collected scats truly belonged to the fishing cat. Thus, we were confident that there would be minimal bias. This is consistent with what Morin et al. (2019) suggested, that imperfect detection of diet items is not a substantial source of error in studies using scat to estimate carnivore diet.

In conclusion, this study examined the dietary habits of fishing cats in a human-dominated wetland in coastal Thailand by collecting fishing cat scats and analyzing them to identify prey species using microscopic techniques. Our findings reveal that fishing cats prey primarily on fish, with climbing perche being the most significant prey, followed by bandicoot rat, domestic chicken, and snakehead murrel. Seasonal variations in dietary composition were not statistically significant; the niche breadth index peaked during the rainy season, much like the diversity index did. The niche overlap index highlighted specialization in fish-based food items during the summer, winter, and rainy seasons. Despite this specialization, the overall niche breadth index suggests that fishing cats exhibit a high level of generalization, supplementing their aquatic diet with terrestrial species. Previous studies demonstrated that fishing cats consume a diverse range of prey items and are generalist predators that do not exclusively specialize in fish, which agrees with previous studies findings of previous studies (Cutter 2015; Khadka 2023; Malla et al. 2023). We formulated two hypotheses about the fishing cat diet in our study area: (i) in this human-dominated landscape, the fishing cat diet primarily comprises domestic and commensal animals, including cultivated fish species, and (ii) the composition of the fishing cat diet shifts to greater fish consumption during the dry season when fish may be easier to catch. Our data led us to reject both our hypotheses, finding that most of their diet comprised native fish species (climbing perch and snakehead murrel). However, they also consumed domesticated and commensal animals to a lesser degree. We also found that although they consumed slightly more fish during the dry summer seasons, there were no significant seasonal dietary shifts. Interestingly, we did find microplastics in scats in this study, and thus, the presence of microplastics in the droppings of fishing cats poses a threat to this species. Recommendations have been proposed for managing the interactions between fishing cats and human settlements. These include implementing livestock and poultry management practices to deter fishing cats, creating barriers in fishponds to restrict their movement, increasing community awareness, setting up compensation programs, and enacting tax legislation to support the maintenance of abandoned fishponds that are crucial habitats for the species. These measures aimed to reduce community conflict and minimize potential reprisals against fishing cats.

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