


## Diet of the Merlin *Falco columbarius* Linnaeus on winter foraging grounds in Western India

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### Abstract

The Merlin *Falco columbarius*, is a small falcon widely distributed across Europe, Asia, and North America. Merlin falcons are winter visitors to north India. They occur from an arid area in Gujarat to far northeast Arunachal Pradesh. Here, we present details of the Merlin's diet on winter foraging grounds in Gujarat and Rajasthan, Western India, based on a combination of direct observations from 2009 to 2023 and secondary data extracted from various social media platforms. A total of 99 hunting events of Merlin with their prey bird were collected from the study areas, including 39 generated from direct observation of falcon hunting and 60 images of falcons with prey items acquired from various electronic media. The higher number (72) of falcon hunting events were noted from Gujarat, while a lower number (27) of observations were noted from Rajasthan. Of the total of 99 hunting events, 83 were carried out by males, 11 by females, and 5 juvenile falcons observed hunting. The hunting times of the falcons were noted in the morning (67%), in the evening (28%), and the least (5%) were recorded in midday periods. Merlins hunted and consumed 17 different types of smaller birds belonging to seven families; the highest number (45.45%) of prey items were the Greater Short-toed Lark, *Calandrella brachydactyla*, from Family Alaudidae and the second highest prey species (7%) was the Barn Swallow, *Hirundo rustica*, Family Hirundinidae. Most of the prey birds were larks of different species (70.70%), with the remaining prey birds in very low numbers. However, the present study supports an earlier study stating that a higher portion of smaller migratory birds are in the diets of Merlin falcons.

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### Introduction

The Merlin falcon, *Falco columbarius* Linnaeus 1758, is a small-sized falcon widely distributed across Europe, Asia, and North America. The sexes differ in adult plumage, with females noticeably larger than males. Due to their widespread distribution, low population densities in remote areas, secretive breeding behavior, and winter seasons spent in open and semi-open habitats, Merlins are challenging to monitor (Bibby and Nattress, 1986;

Ewing et al., 2011; Lusby et al., 2011; Sale, 2015). This species is further recognized into nine subspecies based on plumage morphs and geographical occurrence; with three subspecies occurring in North America, and six subspecies occurring in Europe and Asia (BirdLife International, 2023). However, all the subspecies breed in the northernmost areas of their distributional range and migrate further south for foraging in the winter, non-breeding periods to avoid cool and harsh weather (Warkentin et al., 2020).

The published literature specifies that two subspecies (*Falco columbarius insignis* and *F. c. pallidus*) of Merlin falcon are winter visitors to north India.

They occur from an arid area in Gujarat to far northeast Arunachal Pradesh (Singh, 1995; Naoroji, 2006). *Falco columbarius insignis* widely occurs in northwestern India up to the arid parts of Gujarat and Rajasthan, especially the desert biogeographical zone, during winter, while *F. c. pallidus* is a rare winter migrant in northern India (Rasmussen and Anderton, 2012). Ali and Ripley (2007) mentioned *F. c. insignis* is a 'scarce winter visitor/vagrant?' and that *F. c. pallidus* is 'uncommon/vagrant'. Ganpule and Bhatt (2013) mentioned a third subspecies, *F. c. aesalon*, and its intermediate phase (*F. c. aesalon/insignis*) from the drier-arid parts of Gujarat, India. Thus, Naoroji (2006) finally stated that confusion exists as to whether *F. c. insignis* or both subspecies migrate to the subcontinent, as slight morphological differences are difficult to determine in the field. Its wintering ranges are little known, and similar conclusions were mentioned by Ganpule et al. (2022). Hence, we did not split, or specify any subspecies, of Merlin falcon (Fig. 1) in the present study.

Merlin falcon diets and prey species are well studied with prey being small to medium-sized birds, generally less than 50 g (BirdLife International, 2023). Merlin falcon largely prey on smaller birds of open habitats, such as larks (Alaudidae), pipits and wagtails (Motacillidae), and small waders (Charadriidae). Their diets, also contain a small proportion of mammals, insects, and reptiles (Fox, 1964; Hodson, 1976; Becker and Sieg, 1985; Bibby, 1987; Sodhi and Oliphant, 1993; Cooper, 1996). These previous studies and diet preferences are mostly provided from within the breeding range of the Merlin falcon (Newton et al., 1984; Clarke and Scott, 1994; Heavisides et al., 1995; Rae, 2010; Fernández-Bellon and Lusby, 2011). Most detailed studies published are based on analyses of regurgitated pellets and prey remnants found near nests or around plucking perches (Laing, 1985; Sodhi, 1991; Wiklund, 1996).

Merlin falcon is a challenging species to monitoring in the wild (Lusby et al., 2011; Sale, 2015). This is reflected in the limited information available on their status, population trends, and breeding ecology. However, scant data is available on their prey species, especially on their winter migration grounds in India, as non-breeding habitat areas (Naoroji, 2006). According to Ganpule and Bhatt (2013), wintering Merlin falcons have not been studied in India. Migrating merlin falcons usually prey on smaller-sized waders, larks, pipits, and other small passage migrant birds (Naoroji, 2006).

We present new information on the winter diet of the Merlin falcon, based on data collected from the winter foraging grounds, over 15 years, especially from India's Desert Biogeographical Zone (DBZ), in the states of Gujarat and Rajasthan.

## Material and Methods

The study was designed to systematically collect photographs of Merlin falcons and their prey from the north-western regions of India. This involved combining primary data from fieldwork and secondary data derived from digital social media curation. We used Microsoft Excel 2011 to compile the database for basic statistical analysis (averages and percentages) and preparation of figures.

### Study area

Our study area is the arid region of western India (Fig. 2), which falls within two biotic provinces of the DBZ (Rodger et al., 2002), including the Thar Desert (3A) and Kutch Biospheres (3B). Largely, this vast, open, arid to semi-arid area is known as the winter foraging grounds of Merlin falcons. We selected two intensive study areas within the DBZ, one from each biotic province, the Little Rann of Kutch in Gujarat and Sambhar Lake, Rajasthan, for gathering primary data.

### Little Rann of Kutch (LRK)

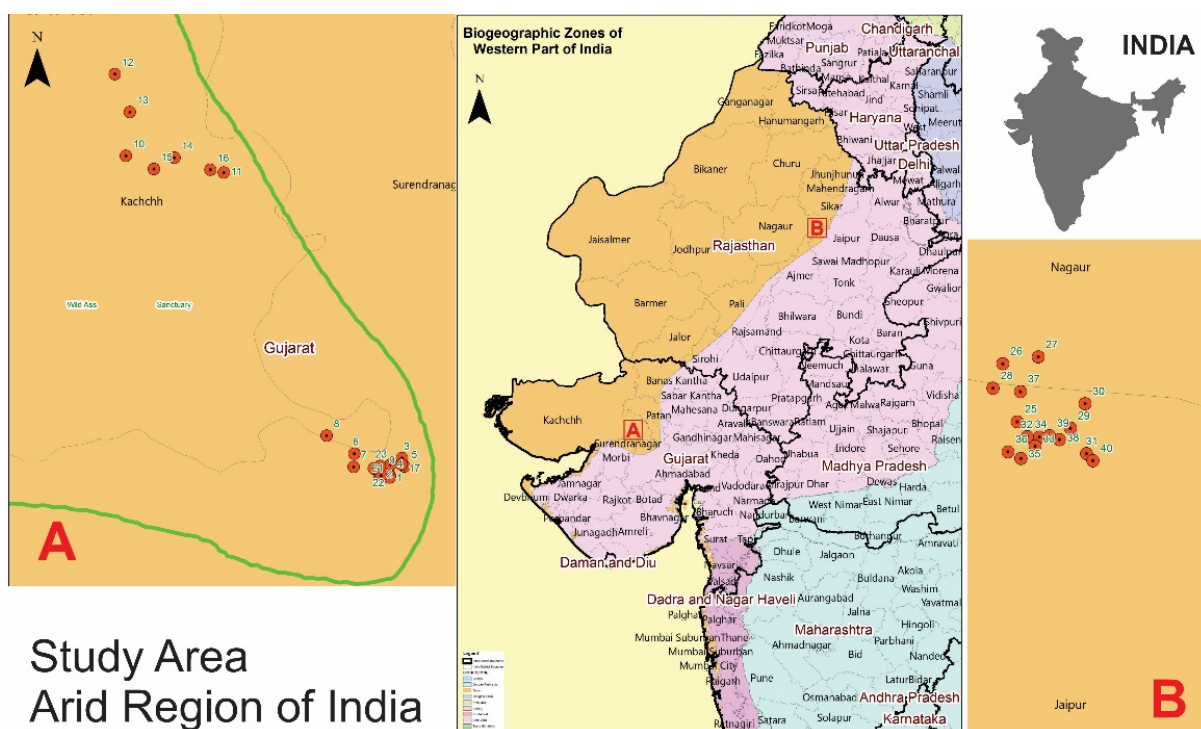
This area lays between 22° 55" to 24° 35" N; and 70° 30" to 71° 45" E and encompasses 4954 km<sup>2</sup> in Gujarat State, India. This Rann is one of the most remarkable and unique landscapes of its kind in the entire world. It is a vast, desiccated, unbroken, bare surface of dark silt, encrusted with salts, which transforms into a spectacular coastal wetland after the monsoon rains. The Rann can be considered a large ecotone, a transitional area between marine and terrestrial ecosystems. During the monsoon, the Rann gets inundated for a period of about one month. It is dotted with about 74 elevated plateaus or islands, locally called 'bets'. The largest plateau, called Pung Bet, has an area of 30.5 km<sup>2</sup>, and the highest island, Mardak, is 55 m in elevation.

### Years and areas of observation

These observations were collected over 15 years from 2009 to 2023; with the highest number of sightings (31) in the year 2020, and just a single observation recorded in the year 2011 (Fig. 5). The sightings of Merlin falcon predation by month are given in Figure 6. These sighting numbers show winter visiting months and activities of the falcon within the study areas.



**Figure 1:** Merlin (*Falco columbarius*) is a small winter visiting falcon found in arid regions of Gujarat and Rajasthan states, India. Photo Credit: Devvratsinh Mori.



**Figure 2:** Detailed map showing the study area within the arid region of the Desert Biogeographical Zone, Western India: (A) Little Rann of Kutch, Gujarat and (B) Sambar Lake, Rajasthan (1–39 show direct sighting localities of *Falco columbarius* which corresponds to Table 1+ Figs. 3–4).

The Little Rann is a protected area known as Wild Ass Sanctuary. The Sanctuary is named after a subspecies of wild ass (*Equus hemionus khur* Lesson), and is home to the last population of this mammal. The vast area of the saline mudflats in the Sanctuary has no vegetation, except on the fringes and on the bets. Vegetation is largely xerophytic, with the ground cover dominated by ephemerals and the monsoon rains trigger their active growth. Although Vilayati Babul *Prosopis juliflora* has colonized the islands and fringes, the islands have a richer floral diversity than that of the fringes. A total of 253 flowering plant species have been listed, of which the number of species that are trees is 18, shrubs 23, climbers/vines 18, herbs 157, and grasses 37. The bets and fringe areas of extensive marine saline flats of the Little Rann of Kutch mainly support a variety of indigenous plants like *Suaeda* spp., *Salvadora persica*, *Capparis decidua*, *Calotropis procera*, *Tamarix* sp., *Aeluropus lagopoides*, *Cressa cretica*, *Sporobolus* spp., and *Prosopis cineraria*. The sanctuary provides many birds with important feeding, breeding, and roosting habitats due to its strategic location on a major bird migration route and its connection with the dynamic Gulf of Kutch. A total of 315 bird species have been recorded from the area (Lepage, 2023).

### Sambhar Lake

Sambhar Lake encompasses over 24,000 hectares and is India's largest inland saltwater wetland. It is located (26°55'34.0" N, 75°05'46.3" E) in the Jaipur district and borders the Ajmer district, in the state of Rajasthan. The Sambhar Lake bowl is made of sedimentary stone and is contained by a 5.1 km long dam. The Aravali Hills surround the lake on all sides. It is recognized as one of the internationally important wetlands under Ramsar Convention (<https://rsis Ramsar.org/ris/464>). This large, dry, barren, flat wetland supports large numbers of native organisms, especially migratory birds and other desert fauna. A total of 83 bird species have been recorded from the area (Kumar, 2005; Sanga, 2009).

### Data collection

We studied the Merlin falcon diet in the winter seasons from 2009 to 2023. The predation behavior and prey species were observed with the help of Binoculars (Nikon monarch 8x42 and Nature Trek 12x50) and images were captured by using high-resolution cameras (Sony- Point and Shoot, and Canon and Nikon D-SLR cameras with telephoto lenses (Sigma 150–600 mm f/5-6.3 DG OS HSM Sports, Nikkor 600 mm f/4 FL ED VR and Tamron AFA022C700 SP 150–600 mm Di VC USD G2 f/5-6.3)). GPS devices were used to determine each observation location and its geo-coordinates (Garmin Etrex 10 and Etrex 20). A purposeful sampling approach was adopted to select specific

locations within the North-western parts of India known for Merlin falcon sightings and wintering foraging movements, including Little Rann of Kutch (Gujarat) and Sambhar Lake (Rajasthan).

We followed standard ethical guidelines to minimize disturbance to the birds and their habitats while maintaining a safe distance to avoid causing them stress during their foraging activities. The secondary data extraction was a non-invasive photo sampling method. Digital images were collected from various social media platforms, including eBird, Birds of India (BOI), Facebook, India Nature Watch (INW), and Birds of Gujarat (BOG) websites, as well as personal communication with a few Indian bird watchers. This information was from areas such as Banni grassland, Little Rann of Kutch, Desert National Park (DNP), Netsi-Ramghar, and Sambhar Lake.

### Identification of prey species

Each image was carefully examined to identify the prey species being captured/consumed by Merlin falcons. All the prey species were identified with the help of field guides (Grimmett et al., 2011; Rasmussen and Anderton, 2012), and bird nomenclature adapted from Praveen et al. (2016). Any uncertainties, or disagreements in identification, were resolved through consensus. The verified Merlin falcon diet photographs were compiled into a comprehensive digital database. Metadata, including location, date, time, and prey species, were associated with each photograph. The compiled data were subject to qualitative analysis to identify dietary preference patterns within the western Indian context. The scope was limited to the Western parts of India, which might not capture the full dietary spectrum of Merlin across the entire country. Seasonal variations and potential biases in observation could influence the results. The methodology outlined above allowed for the systematic collection, analysis, and interpretation of Merlin diet photographs from the Western parts of India, contributing to a better understanding of their feeding habits and ecological role in the region.

### Results

A total of 99 hunting events of Merlin falcons with their prey birds were collected from the study areas and scrutinized for the study, including 39 events generated from direct observation of hunting (Table 1, Figs. 2A, B, 3 and 4), and 60 images of merlin falcon with kills acquired from various electronic media (Supplementary file). The overall total of 99 hunting events, included 83 enacted by males, 11 by females, and 5 by juvenile falcons.

**Table 1:** Details of chronological observations on Merlins (*Falco columbarius*) hunting and prey bird species in diets, in the study areas of Little Rann of Kutch, Gujarat State and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India (M= Male; F= Female).

No.	Year	Sex	Date	Time (H)	GPS Lat-Long	Species name	Scientific name	Image
<b>Little Rann of Kutch, Gujarat</b>								
1	2009	M	17 Jan. 2009	07:44	23°07'57.3"N 71°43'33.6"E	Barn Swallow	<i>Hirundo rustica</i> Linnaeus, 1758	Fig. 3/1
2	2009	M	23 Feb. 2009	08:09	23°07'55.5"N 71°43'08.4"E	Sand Lark	<i>Alaudala raytal</i> (Blyth, 1845)	Fig. 3/2
3	2011	M	1 Dec. 2011	16:44	23°08'35.5"N 71°44'07.2"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/3
4	2012	M	15 Jan. 2012	08:35	23°07'53.0"N 71°43'36.3"E	Bimaculated Lark	<i>Melanocorypha bimaculata</i> (Ménétries, 1832)	-
5	2012	M	22 Dec. 2012	08:54	23°08'15.6"N 71°44'13.2"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/5
6	2013	M	12 Jan. 2013	16:44	23°08'45.8"N 71°42'04.4"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
7	2013	M	2 Dec. 2013	16:58	23°08'14.7"N 71°42'02.4"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/7
8	2014	F	15 Feb. 2014	08:20	23°09'28.8"N 71°40'52.5"E	Barn Swallow	<i>Hirundo rustica</i> Linnaeus, 1758	-
9	2014	M	28 Feb. 2014	08:46	23°08'02.5"N 71°43'15.7"E	Unidentified Lark	Calandrella Group	-
10	2014	M	13 Dec. 2014	07:50	23°20'30.7"N 71°32'15.9"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/10
11	2014	M	26 Dec. 2014	16:36	23°19'50.8"N 71°36'28.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
12	2015	M	8 Feb. 2015	18:35	23°23'43.8"N 71°31'47.0"E	Unidentified Lark	Calandrella Group	Fig. 3/12
13	2016	M	9 Jan. 2016	08:17	23°22'13.7"N 71°32'26.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
14	2017	M	12 Dec. 2017	16:42	23°20'25.9"N 71°34'21.1"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
15	2017	M	26 Dec. 2017	16:52	23°19'59.3"N 71°33'28.1"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/15
16	2017	M	28 Dec. 2017	09:52	23°19'57.7"N 71°35'53.3"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/16
17	2018	M	15 Jan. 2018	08:41	23°08'20.8"N 71°44'06.0"E	Sand Lark	<i>Alaudala raytal</i> (Blyth, 1845)	Fig. 3/17
<b>Sambhar Lake, Rajasthan</b>								
18	2020	M	8 Mar. 2020	17:50	26°55'58.0"N 75°02'46.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
19	2020	M	27 Jan. 2020	08:00	26°56'58.9"N 75°02'29.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
20	2020	M	28 Jan. 2020	08:13	26°57'06.1"N 75°03'10.7"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/20
<b>Little Rann of Kutch, Gujarat</b>								
21	2020	M	12 Apr. 2020	08:42	23°07'58.6"N 71°43'29.5"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/21
22	2020	M	19 Dec. 2020	08:54	23°07'49.3"N 71°43'35.2"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/22
23	2020	M	21 Dec. 2020	07:49	23°07'53.6"N 71°43'12.8"E	Barn Swallow	<i>Hirundo rustica</i> Linnaeus, 1758	Fig. 3/23
24	2020	M	24 Dec. 2020	07:47	23°08'20.1"N 71°43'38.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/24
25	2020	M	27 Dec. 2020	16:52	23°08'10.7"N 71°42'54.4"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/25
26	2020	M	28 Dec. 2020	17:09	23°08'16.8"N 71°43'10.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/26
<b>Sambhar Lake, Rajasthan</b>								
27	2021	M	16 Dec. 2021	11:27	26°56'33.2"N 75°02'17.5"E	Barn Swallow	<i>Hirundo rustica</i> Linnaeus, 1758	Fig. 3/27
28	2022	M	14 Mar. 2022	17:41	26°55'51.1"N 75°03'48.5"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/28
29	2022	M	20 Nov. 2022	13:25	26°56'16.9"N 75°04'06.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/29
30	2023	M	13 Dec. 2023	07:15	26°55'24.4"N 75°04'07.6"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	-
31	2023	M	6 Jan. 2023	13:04	26°55'41.7"N 75°03'12.0"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/31
32	2023	M	6 Feb. 2023	11:32	26°55'32.3"N 75°03'07.1"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 3/32
33	2023	M	7 Feb. 2023	08:30	26°55'42.1"N 75°02'57.9"E	House Sparrow (F)	<i>Passer domesticus</i> (Linnaeus, 1758)	Fig. 3/33
34	2023	F	8 Feb. 2023	11:31	26°55'19.2"N 75°02'50.4"E	Sand Lark	<i>Alaudala raytal</i> (Blyth, 1845)	Fig. 3/34
35	2023	F	9 Feb. 2023	11:31	26°55'26.3"N 75°02'35.0"E	Rufous-tailed Lark	<i>Ammomanes phoenicura</i> (Franklin, 1831)	Fig. 4/35
36	2023	M	5 Mar. 2023	08:01	26°56'29.6"N 75°02'49.6"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 4/36
37	2023	M	10 Mar. 2023	8:32	26°55'39.2"N 75°03'35.7"E	Bimaculated Lark	<i>Melanocorypha bimaculata</i> (Ménétries, 1832)	Fig. 4/37
38	2023	M	13 Mar. 2023	07:20	26°55'43.3"N 75°03'23.8"E	Greater Short-toed Lark	<i>Calandrella brachydactyla</i> (Leisler, 1814)	Fig. 4/38
39	2023	M	15 Mar. 2023	07:30	26°55'16.9"N 75°04'15.2"E	House Sparrow (M)	<i>Passer domesticus</i> (Linnaeus, 1758)	-



**Figure 3:** Chronological observations of direct sightings of Merlin Falcons (*Falco columbarius*) with prey birds of the study areas of Little Rann of Kutch, Gujarat state and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India: numbers 1–34 correspond with Table 1.

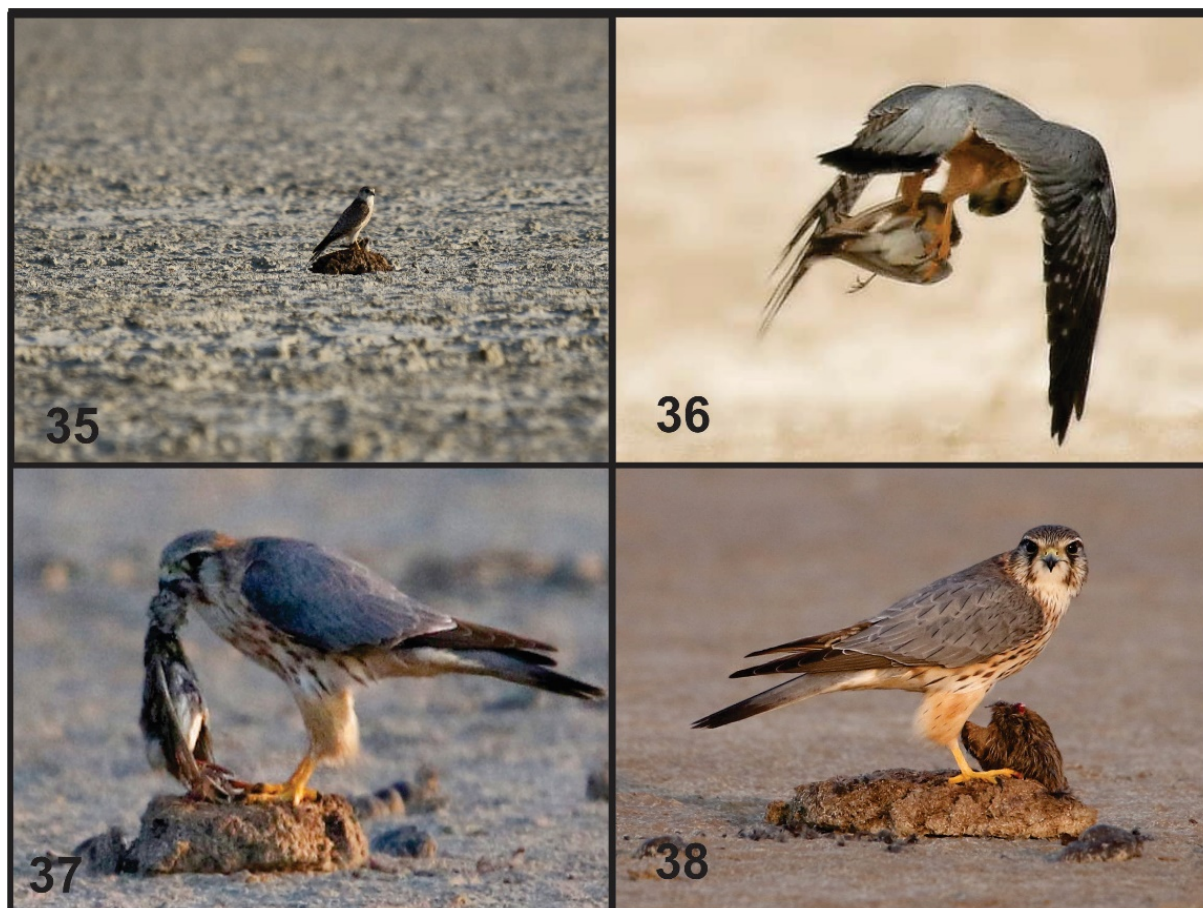
The highest number of falcon hunting events (72) were noted from Gujarat, and the lowest number of hunting observations were recorded from Rajasthan (27). The maximum hunting sightings were 68 from LRK, followed by 21 sightings at Sambhar Lake, and then each of 4 records from Banni areas and DNP. There were fewer than three sightings from Netsi Lake and its surrounding areas.

#### Hunting times and prey bird species

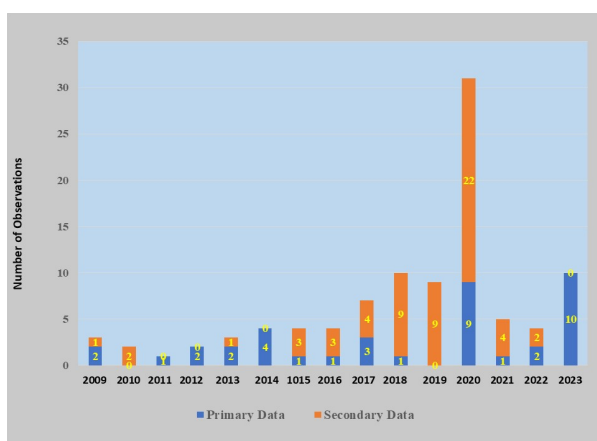
The hunting times of the falcons were noted through

direct observation, with the highest number of hunting events (26, 67%) noted in the morning period (0700–1200 h.), and 11 (28%) hunting events observed in the evening (1601–1900 h.). At least two hunting events (5%) were recorded at midday during the hours of 1201–1600 (Table 1 and Fig. 7).

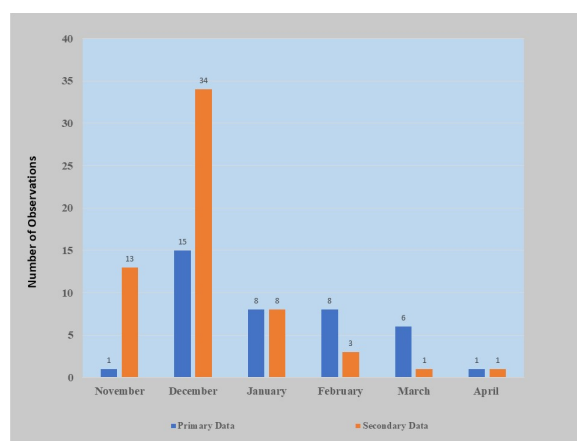
Merlin falcons hunted and consumed many different types of small birds; 17 species belonging to seven families (Table 2).



**Figure 4:** Chronological observations of direct sightings of Merlin Falcons (*Falco columbarius*) with prey birds of the study areas of Little Rann of Kutch, Gujarat state and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India: numbers 35–38 correspond with Table 1.



**Figure 5:** Direct sighting records of Merlin Falcons (*Falco columbarius*) within the 15 years of the study (2009–2023) in the areas of Little Rann of Kutch, Gujarat state and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India.



**Figure 6:** Direct sighting records by month of Merlin Falcons (*Falco columbarius*) in the arid regions of Little Rann of Kutch, Gujarat state and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India.

The highest number of prey items were the Greater Short-toed Larks *Calandrella brachydactyla* (Leisler) (45, 45.45%), and the second highest prey species (7, 7%) was the Barn Swallow *Hirundo rustica*

Linnaeus, from the Family Alaudidae and Hirundinidae, respectively. Most of the hunted bird species were larks (70, 70.70%), including 15 unidentified larks. The remaining prey birds were

very few in number but include the Desert Wheatear *Oenanthe deserti* (Temminck), Tawny Pipit *Anthus campestris* (Linnaeus), Water pipit *Anthus spinoletta* (Linnaeus), unidentified Pipit (*Anthus* sp.), Western Yellow Wagtail *Motacilla flava* (Linnaeus), Common Babbler *Argya caudata* (Dumont), House Sparrow *Passer domesticus* (Linnaeus), and an unidentified Quail (*Perdica* sp.). A total of twelve prey birds were never unidentified.

## Discussion

The present study area is an arid region of western India, part of Gujarat and Rajasthan states and is known for being the foraging ground for many migratory raptors, including winter migrating Merlin falcons (Naoroji, 2006; Grimmer et al., 2011). Naoroji (2006), stated that a very small number of Merlin falcons visit the area in the winter season, and subsequent researchers have supported this statement (Ganpule and Bhatt, 2013; Naoroji and Sanga, 2013; Ganpule et al., 2022). During the study, we similarly saw only a few falcons in the study areas. Therefore, a low encounter rate of 6.6 birds/annum was achieved within a span of 15 years. This low encounter rate suggests that the Merlin is a rare winter vagrant migratory visitor in the western states of India. Therefore, we recorded some fluctuations in the observations across a span of 15 years (See Fig. 5).

The highest number hunting events were observed in the morning (67%) and evening (28%), and only 5% of hunting was noted in the middle of the day. These hunting activities indicate that falcons avoid foraging in harshest and hottest periods of the day in these deserts. The temperatures of the DBZ in India show immense fluctuations, especially in winter, with diurnal temperatures of 35 C° and night temperatures going below -2 C° (Chandra et al., 2021).

The diet of Merlin falcons has been previously stated to comprise 80% birds, and the remaining small proportion is insects (15%) and small-sized mammals (5%) (Brown and Amadon, 1968; Bibby, 1987; Sodhi and Oliphant, 1993; BirdLife International, 2023). Merlin falcons are opportunistic hunters and usually hunt an area's most abundant and available prey species (Clarke and Scott, 1994; Heavisides et al., 1995; Petty et al., 1995; McElheron, 2005; Rae, 2010). Therefore, Merlin falcon utilize a wide spectrum of prey species, and diet preferences change with area and season (Newton et al., 1984; Fernández-Bellon and Lusby, 2011). We recorded 17 different species of small birds in the Merlin falcon diet, with a notably large amount (66.66%) consisting of small-sized migratory birds, including 45% Greater Short-toed Lark *Calandrella brachydactyla* (Fig. 8) (Table 2).

The high portion of small migratory birds in their prey supports earlier studies that Ydenberg et al. (2007) and Bourbour et al. (2019) proposed. A similar hypothesis was supported in a few other

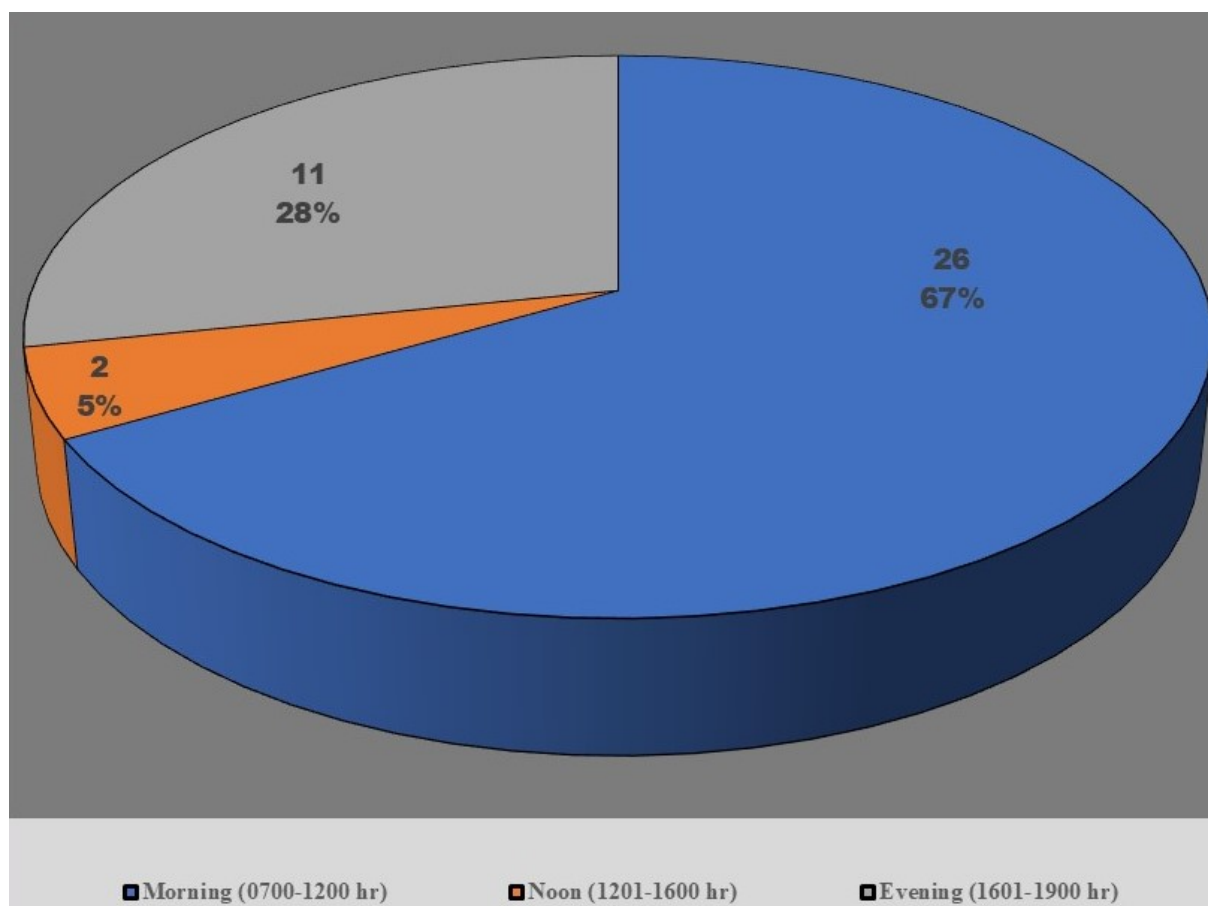
raptors, including the Peregrine Falcon, *Falco peregrinus* Tunstall, by Aborn (1994). Bourbour et al. (2021) found the same result when they collected trace prey DNA from the beaks and talons of North American migrating populations of Merlins, and revealed that songbird prey fueled the autumn migration, based on DNA metabarcoding.

Merlin falcons exhibit sexual dimorphism, with the sexes differing in adult plumage, and females noticeably larger than males (BirdLife International, 2023). Bourbour et al. (2021) statistically tested, and found a significant relationship, between prey size selection and sex, but we did not find any notable difference between prey size and sex in the present study. This might be due to the higher numbers of male falcons (87.87%) observed and a comparatively smaller sample size.

**Table 2:** List of prey birds of winter migrating Merlins (*Falco columbarius*) in the study area of Little Rann of Kutch, Gujarat state and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India. M= Migratory; R= Resident.

Family	No.	Common English name Scientific name	No. of Prey/Kills
		Greater Short-toed Lark	
	1	<i>Calandrella brachydactyla</i> (Leisler, 1814)	M 45
		Bimaculated	
	2	Lark <i>Melanocorypha bimaculate</i> (Ménétries, 1832)	M 02
		Rufous-tailed Lark	
Alaudidae	3	<i>Ammomanes phoenicura</i> (Franklin, 1831)	R 01
	4	Sand Lark <i>Alaudala raytal</i> (Blyth, 1845)	R 05
		Humes Short-toed lark	
	5	<i>Calandrella acutirostris</i> Hume, 1873	M 02
	6	Unidentified Lark ( <i>Calandrella</i> sp.)	- 12
	7	Unidentified Crested Lark ( <i>Galerida</i> sp.)	- 03
Hirundinidae	8	Barn Swallow <i>Hirundo rustica</i> Linnaeus, 1758	M 07
Muscicapidae	9	Desert Wheatear <i>Oenanthe deserti</i> (Temminck, 1825)	M 01
	10	Tawny Pipit <i>Anthus campestris</i> (Linnaeus, 1758)	M 01
	11	Water pipit <i>Anthus spinoletta</i> (Linnaeus, 1758)	M 01
Motacillidae	12	Unidentified Pipit ( <i>Anthus</i> sp.)	- 02
		Western Yellow Wagtail	
	13	<i>Motacilla flava</i> Linnaeus, 1758	M 01
Timalidae	14	Probably Common Babbler <i>Argya caudata</i> (Dumont, 1823)	R 01
Passeridae	15	House Sparrow <i>Passer domesticus</i> (Linnaeus, 1758)	R 02
Turnicidae	16	Unidentified Quail ( <i>Perdica</i> sp.)	- 01
	17	Bird Species Not-identified	- 12
Totals			99





**Figure 7:** Pie chart showing Merlin Falcon (*Falco columbarius*) hunting and foraging activity timing pattern in the arid regions of Little Rann of Kutch, Gujarat state and Sambhar Lake, Rajasthan State, Desert Biogeographic Zone, India.



**Figure 8:** Male Merlin Falcon (*Falco columbarius*) with a kill (Greater Short-toed Lark *Calandrella brachydactyla*). Photo Credit: Devvratsinh Mori.

Ganpule and Bhatt (2013) noted that almost no data regarding Merlin falcon winter site fidelity and winter residency in India was available. The present study could shed some light on the fidelity of winter visits of Merlin falcons, but we cannot explain the occurrence of a higher number of males compared to females and juveniles in the study. However, a study from Sweden by Wiklund (1996), showed similar uneven sex ratios, higher in males than in females in breeding areas.

It is important to know raptor diets during migration when birds are moving quickly over vast distances, across broad geographical areas, and when foraging cannot be observed (Klaassen et al., 2014; Marra et al., 2015; Bourbour et al., 2019). Eurasian Merlin falcon breeding grounds are in northern forests from the United Kingdom to Siberia and on the Asian steppe regions from the Aral Sea to the Altai Mountains, but their migration is south to North Africa, Middle East, Iran, South and East Asia in the winter season (BirdLife International, 2023). Therefore, the present study of the diet and prey selection of migrant Merlin falcon could help us to know more about this species life cycle and enlighten conservation strategies for the important global species.

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### Author contributions

Design and development of concept: Raju Vyas, Devvratsinh Mori; Fieldwork: Devvratsinh Mori, Gourav Dadhich, Raju Vyas; Data analysis: Raju Vyas, Devvratsinh Mori; Manuscript writing: Raju Vyas, Devvratsinh Mori.

### Conflicts of interest

The authors declare that there are no conflicting issues related to this research article.

### Supplementary file

Dietary of Merlin *Falco columbarius* at winter foraging grounds in Western India, available at: [https://jad1.lu.ac.ir/article\\_719480.html](https://jad1.lu.ac.ir/article_719480.html)

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