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Diet of Breeding Caspian Terns *Hydroprogne caspia* at Banc d'Arguin, Mauritania, is Diverse and Differs Between an Offshore and an Inshore Site

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Abstract.—Studying the breeding patterns and diet of conspicuous predators is a useful way to understand the structure of marine coastal food webs. The Banc d'Arguin, Mauritania, hosts a significant portion of the West African population of a widespread and conspicuous fish predator, the Caspian Tern *Hydroprogne caspia*. At two small islands, the relatively offshore Arel and the inshore Zira, in the Parc National du Banc d'Arguin, the size of the colonies and the timing of the first wave of breeding were measured during the breeding seasons 2015–2018. At Arel, the summed number of nests counted varied between 128 in 2015 to 306 in 2018 and at Zira between 375 in 2015 to 279 in 2018. Breeding at Arel commenced about a month later than at Zira. During the breeding season of 2016, the diet of Caspian Terns was assessed by the identification of hard items found in pellets collected near nests. All of these appeared to be parts of fish (e.g., otoliths, bones, vertebrae, scales, bullae and atlas). Despite the effort, for Arel 47% and for Zira 45% of the fish parts remained unidentified. Nevertheless, diet composition differed in interesting ways between the two colonies. At offshore Arel, the identifiable part of the diet consisted primarily of pelagic species, namely Hemiramphidae, while at inshore Zira, pellets consisted primarily of benthopelagic prey, namely Cichlids. Repeated sampling across years may show whether the evidence for earlier inshore breeding holds up and is consistently correlated with dietary differences. Received 17 Sep 2023, accepted 27 Jan 2025.

Key words.—fish bones, marine biodiversity, prey identification, seabirds, West Africa

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Terns (family Laridae) are important predators in coastal aquatic ecosystems worldwide. Among the most widespread is the Caspian Tern *Hydroprogne caspia*, which breeds in coastal and freshwater habitats on all the world's continents, except South America and Antarctica (del Hoyo *et al.* 1996). Despite being the largest and therefore perhaps the most conspicuous tern species, diet and breeding of Caspian Terns remain relatively little studied, particularly with respect to the populations in Asia and Africa (Gaglio *et al.* 2021).

In coastal West Africa, Caspian Terns can be found breeding from Mauritania to Guinea, with an estimated total breeding population of 45,000–60,000 birds (van Roomen *et al.* 2015; Correia *et al.* 2018). At the Banc d'Arguin National Park in Mauritania, Caspian Terns breed on several small sandy islands

(i.e., Ardent, Flamants, Marguerite, Zira, Nair, Niroumi, Arel, Kiaone, Touffat, Cheddidi and Pélican; de Balsac and Mayaud 1962; Campredon 1987; Ould Sidi Mohamed 2013) as well as rocky Arel. The breeding population of Caspian Terns in the Banc d'Arguin varied between 1200 and 2600 nests in 1960–1985 to between 250 and 600 nests in 1990–1995, but is now more variable with a record of 10,900 nests in 1998, and nearly 6000 pairs in 1997 and 2004 (Isenmann 2006; Isenmann *et al.* 2010).

According to Campredon (1987), Caspian Terns in the Banc d'Arguin show three waves of breeding: one from mid-February to late June, one from July to late September and a very late one from October to early January, with most breeding occurring in the first wave. Further south, in Guinea-Bissau, there is indication that breeding also occurs at multiple



Figure 1. The left panel shows a satellite image of the Atlantic coast of Mauritania from the peninsula of Cap Blanc in the north to Cap Timiris in the south, with the inset showing the study area. The right panel indicates the extent of terrestrial habitat (with yellowish colour) and marine, mostly intertidal flats (in green and greyish tones) with gullies (in blue), with Arel on the left and Zira on the right.

times of the year (Insambé 2022). After breeding, Caspian Terns likely leave the Banc d'Arguin to winter further south (Isenmann *et al.* 2010). Both the timing of breeding and the variability in population size may be influenced by fluctuations in prey availability, but neither the variability in prey choice, nor that in the resource base is particularly well known in West Africa (Veen *et al.* 2018). To enhance our understanding of the performance of piscivorous seabirds within a context of environmental change (including global warming), this project aimed to develop local knowledge and expertise to study the diet, dietary overlaps, and spatiotemporal changes in prey choice of the Caspian Tern. To establish a base for future research before embarking on the use of advanced techniques (e.g., eDNA, metabarcoding, digital photography or stable isotopes), we aimed to develop an assessment of prey species and their relative contributions to the diet of Caspian Terns at Banc d'Arguin.

From 2015–2018 we studied the number of nesting pairs on two islands representing the range of nesting options for Caspian Terns within the Parc National du Banc d'Arguin: Arel and Zira. Arel is a relatively offshore island, and although surrounded by intertidal mudflats and channels, has deeper oceanic water in close proximity. Zira is separated from

the mainland shore by a single deep channel and is surrounded by intertidal mudflats. In 2016 we examined dietary differences from pellets collected at both sites. If terns concentrate their foraging close to their breeding colony (Leopold 1993; Campredon 2000; Camphuysen *et al.* 2012; Veen *et al.* 2012a,b; 2018), we expect the birds from the colonies at Arel and Zira to use foraging areas with different characteristics, leading to different breeding chronologies and different diets.

METHODS

Study Area

Fieldwork was carried out on Arel (19° 54'2.3"N, 16° 30'13.1"W) and Zira (19° 52'9.1"N, 16° 17'46.4"W) (in the Parc National du Banc d'Arguin (Figure 1). The national park is home to 16 waterbird colonies, including those of an endemic subspecies of Grey Heron *Ardea cinerea monicae* and of Eurasian Spoonbill *Platalea leucorodia balsaci* (Campredon 2000; Isenmann 2006; El-Hacen *et al.* 2013). The rocky island of Arel, ca. 500 m in diameter, is situated 20 km away from the mainland coast, just a few km away from oceanic waters. At Arel, the nests consisted of scrapes in bare sand. Zira is just off the mainland coast, separated from it by a 500 m wide deep channel. Zira is a flat sandy island built up of shell material and dry seagrass. It is surrounded by large expanses of tidal flats with creeks and channels of varying depth. Caspian Terns use beds of dried seagrass to build shallow nests.

Field Observations

From March to August 2015–2018, we visited Arel and Zira as close to monthly as possible, although logistics of obtaining transport made this challenging, resulting in 1–6 trips to Arel annually and 3–6 trips to Zira annually with the most visits occurring in 2016 (Table 1). Arriving on an island, we first observed the general situation and the state of the colony by telescope. Then we went into the colony to count the number of nests with eggs or very small chicks (1–2 days old). As incubation takes 24 to 27 days (Fetterolf and Blokpoel 1983), the nests with eggs or very small chicks counted during the first visit would have yielded larger chick during the second visit, and nests with eggs or small chicks would be newly established (Bergman 1953). In this way, the sum of ‘young’ nests over a season gave us an index of the relative abundance of breeding pairs in different years. One-egg clutches are likely incomplete, but enable us to back calculate the start of egg-laying assuming intervals of 2–3 days between each laid egg (Bergman 1953). To avoid undue disturbance, the time spent in the colonies was limited to 40 min. All field observations were carried out by the first author.

Pellet Analyses

We collected 65 pellets around the nests in Arel (March–May 2016) and 58 in Zira (March–July 2016). The freshly regurgitated pellets were collected around 20 nests that contained eggs to make sure that the pellets would reflect the diet of adults, as it has previously been shown that adults may feed different prey to their young than what they eat themselves (Gaglio *et al.* 2021). Pellets were stored together in plastic bags at room temperature and remained intact in the bag. In the laboratory, pellets were separated from each other and individually bagged and labeled. The individual pellets were then soaked in water so that all the hard parts could be distinguished and identified. Pellet analysis involved combining the identification of otoliths with the identification and counting of different bones (premaxillae, dentaries molars, and teeth, cleithra, bullae, vertebrae, urostyles, and others; Camphuysen and Henderson 2017). All hard parts were used, as using otoliths only has been shown to negatively bias diet characterizations (Correia *et al.* 2018). The parts were identified to the lowest possible taxonomic level under a binocular microscope with the help of different guides (Maigret and Ly 1986; Bellemans *et al.* 1988; Veen *et al.* 2003; Veen and Hoedemakers 2005; Camphuysen and Henderson 2017). The minimum number of individual fish of a taxon from which the different body parts could have originated was then calculated.

RESULTS

The abundance of breeding Caspian Terns on Arel varied between a sum of 128 newly established nests in 2015 and 306 nests in 2018 (Table 1). During this time numbers

Table 1. Field effort and number of nests with eggs or freshly hatched chicks of Caspian Terns in the colonies at Arel and at Zira during 2015–2018. Dashes indicate missing observations, i.e., the absence of visits.

Day	Month	Year	Arel	Zira
—	March	2015	—	—
9	April	2015	—	247
7	May	2015	128	—
15	May	2015	—	128
—	June	2015	—	—
17	July	2015	—	0
10	March	2016	0	—
14	March	2016	—	41
11	April	2016	78	—
12	April	2016	—	51
13	May	2016	202	—
15	May	2016	—	181
8	June	2016	—	73
10	June	2016	60	—
17	July	2016	—	1
23	July	2016	15	—
10	August	2016	0	—
14	August	2016	—	0
1	March	2017	—	39
9	April	2017	39	—
10	April	2017	—	129
7	May	2017	—	92
11	May	2017	234	—
10	June	2017	—	43
11	June	2017	47	—
9	July	2017	0	—
13	July	2017	—	0
28	February	2018	0	—
2	March	2018	—	9
—	April	2018	—	—
11	May	2018	188	—
13	May	2018	—	259
21	June	2018	118	—
25	June	2018	—	11

of breeding Caspian Terns on Zira varied between a sum of 375 newly established nests in 2015 and 279 nests in 2018. At Arel, Caspian Terns would have commenced breeding in late March. Peak laying occurred in May and some eggs were still produced in July (Table 1). At Zira, egg laying was a month earlier, in late February rather than late March, with a peak in April (2015 and 2017) or in May (2016 and 2018), but with some late breeders encountered into July (Table 1).

The pellets consisted entirely of fish remains, but for Arel 47% and for Zira 45% of the fish parts remained unidentified to family or species levels. As shown in Figure 2, at

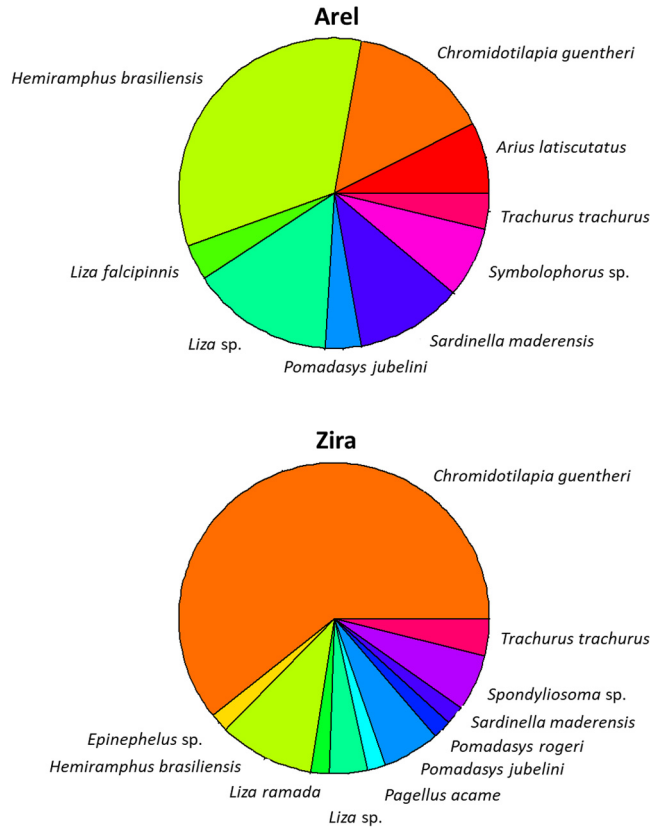


Figure 2. Diet of Caspian Terns based on analysis of all hard parts of fish (i.e., otoliths, bones and scales) found in pellets collected at Arel ($n = 65$) and Zira ($n = 58$) during the breeding season of 2016. The unit of measurement is evidence for a single individual fish (not weighed according to mass), the minimum number of which were counted per species. Note that of the prey remains, for Arel 47% remained unidentifiable, and for Zira 45% remained unidentifiable.

offshore Arel, we identified prey of the at least eight different species with *Hemiramphus brasiliensis* (family Hemiramphidae, 9 individual fish) contributing most to the identifiable fish remains. At inshore Zira (Fig. 2), we identified at least 10 different prey species of which most were Cichlidae *Chromidotilapia guentheri* (31 fish).

DISCUSSION

On the basis of the current field effort, with the latest visits taking place in August 2016, we were unable to verify if the breeding of Caspian Terns occurred in the three waves suggested by Campredon (1987). However, we can conclude that, at least in 2016, the birds at Zira started breeding earlier in the year than at Arel. Repeated sampling across a series of

years is now necessary to show whether this difference occurs across years, and whether it is correlated with the dietary differences between offshore Arel and inshore Zira.

Caspian Terns are generally considered opportunistic predators, as their diet often reflects the relative abundance of the benthopelagic fish of a given foraging area (Roby *et al.* 2002; Dunlop and McNeill 2017; Correia *et al.* 2018; Gaglio *et al.* 2021). Previously, Veen *et al.* (2018) reported Caspian Terns in the Banc d'Arguin area as feeding mostly on mullet Mugilidae, as has been found in South Africa (Gaglio *et al.* 2021) and Western Australia (Dunlop and McNeill 2017). Further south in West Africa, in the coastal waters of Guinea-Bissau, Correia *et al.* (2018) reported Caspian Tern as feeding mostly on pelagic fish, with Clupeidae (mostly *Sardinella maderensis*) dominating the diet at all locations and seasons.

It is interesting that of the prey species identified, only three are small-bodied species, i.e., species that are ingestible even as adult fish, i.e., *Hemiramphus brasiliensis* at Arel and Zira, *Symbolophorus* species at Arel and *Chromidotilapia guentheri* at Zira (Fig. 2). Although Caspian Terns are known to eat fish up to 25 cm in length (Correia *et al.* 2018), at Banc d'Arguin Caspian Terns thus seem to feed on small, in many cases juvenile, fish. The observation that the fish species selected by Caspian Terns reproduce throughout the year (Sall Amadou Abderahmane, pers. comm.), suggests that there should be suitable fish year-round.

Our results show that among terns from Arel, there was indeed a high proportion of pelagic fish, especially *Hemiramphus brasiliensis*, while the pellets collected at inshore Zira showed mostly benthopelagic fish, especially the cichlid *Chromidotilapia guentheri* (an interesting 'freshwater' species recorded at Banc d'Arguin and captured by the local Imraguen fishermen; Kidé *et al.* 2015, Sall Amadou Abderahmane, pers. comm.). Figure 2 further suggests that the diet of Caspian Terns breeding in the Banc d'Arguin likely differs between birds breeding in a relatively offshore and an inshore colony. This finding is in line with previous work, which showed that Caspian Terns breeding in nearby colonies (<30 km apart) can differ in their diets, most probably reflecting spatiotemporal variation in the composition of fish available to the birds (Roby *et al.* 2002).

Clearly, the present work is only the beginning of the quantitative assessment of the diet of Caspian Terns at Banc d'Arguin; many fish remains could not be identified. Our inability to identify many fish items not being due to these bones and otoliths showing wear and tear, but rather to us failing to find the key information in existing works of reference (hinting at unknown fish), leads us to recommend the build-up of a reference collection of the small fish that are potential prey of the Caspian Terns and other waterbirds. This should be based on all hard part remains of fish, according to the specifications of Camphuysen and Henderson (2017). We advise to start a long-term monitoring study on the breeding ecology of these and other terns, including the standardized and

regular collection of pellets. With all the foreseen changes in our environments stemming from changing human use (e.g., Lemrabott *et al.* 2023, 2024 on changes in fishery and fish communities) and changing climates and sea levels, this may have an urgency that few people realize.

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