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The diet of Gull-billed Tern *Gelochelidon nilotica* breeding in the Po Delta (NE Italy)

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Abstract - The present study provides the first data on the diet of Gull-billed Terns (*Gelochelidon nilotica*) nesting in the Po Delta. Four hundred and forty-five prey items were found in pellets collected on a colony in a fish farm on June 11, 2018. Pellets contained mostly *Invertebrata* (403 items), of which the majority were *Insecta* (50.8%, mainly *Orthoptera*: 22.7%) and, to a lesser extent, *Crustacea* (22%, exclusively Red Swamp Crayfish *Procambarus clarkii*) and *Mollusca* (17.8%, mostly *Gasteropoda*: 16.2%), whereas *Vertebrata* accounted for only 9.4% (42 items, mostly *Amphibia*: 8.3%). Gull-billed Terns nesting in the Po Delta follow a diet with a predominance of *Insecta*, but with significant shares of *Crustacea* and *Mollusca* and, to a lesser extent, *Amphibia*, thus confirming the flexibility of the species in adapting to the prey availability of the foraging area.
Key words: breeding, food, foraging, *Gelochelidon nilotica*, Gull-billed Tern, Po Delta.

Riassunto - La dieta della Sterna zampenere *Gelochelidon nilotica* nidificante nel Delta del Po.
Il presente studio fornisce i primi dati sull'alimentazione della sterna zampenere nidificante nel Delta del Po. Sono stati rinvenuti 445 frammenti di prede da borre raccolte in una colonia monospecifica in data 11 giugno 2018. Le borre contenevano principalmente invertebrati (403 frammenti), di cui la massima parte insetti (50,8% dei frammenti totali, principalmente ortotteri: 22,7%) ed in misura minore crostacei (22%, esclusivamente gambero della Louisiana *Procambarus clarkii*) e molluschi (17,8%, principalmente gasteropodi: 16,2%), mentre i vertebrati rappresentavano solo il 9,4% (42 items, principalmente anfibi: 8,3%). Le Sterne zampenere nidificanti nel Delta del Po seguono una dieta varia con una preminenza di insetti, ma con quote significative di crostacei e molluschi ed in misura minore di anfibi, confermando così la flessibilità della specie nell'adattarsi alla disponibilità trofica dell'area di nidificazione.
Parole chiave: alimentazione, biologia riproduttiva, Delta del Po, *Gelochelidon nilotica*.

INTRODUCTION

The Gull-billed Tern is a colonial *Charadriiform* species with a worldwide distribution, with a breeding range including all the five continents, being found breeding in Europe, Asia, Africa, the Americas and in Oceania (del Hoyo *et al*., 1996). The global population have been estimated at 150,000-420,000 individuals (Delany & Scott, 2006), of which 6,600-21,200 pairs have been ascribed to the European contingent (BirdLife International 2024). Six subspecies have been identified, the nominate *G. n. nilotica* inhabiting Europe and African breeding grounds (Sanchez *et al.*, 2004), including Italy with an estimated population of around 500 pairs (EIONET, 2021).

The Gull-billed Tern has been studied in detail with regard to various aspects of reproductive biology in different nesting areas across its breeding range: from the United States to Russia to south-central Europe to the Mediterranean (Møller, 1982; Costa, 1984; Cramp, 1985; Cabo & Sanchez, 1986; Bogliani *et al*., 1990; Quinn & Wiggins, 1990; Goutner, 1991; Sanchez *et al*., 1991; Ataei *et al*., 2014; Bertolero & Rivaes, 2015; Britto *et al*., 2018; Scarton & Valle, 2020, Wu *et al*., 2020; Hering *et al*., 2021; Valle & Scarton, 2021 Goodenough *et al*., 2023). The species has shown remarkable flexibility in nesting site selection using brackish-water, freshwater and marine areas (Møller, 1982; Quinn & Wiggins, 1990; Sanchez et al. 2004). Feeding habits have also been thoroughly investigated in several populations located in many parts of the world, including Europe, Africa, Asia and North America (see Cramp, 1985 for a review). This also applies to Italy, where the population inhabiting the Valli di Comacchio wetland has been investigated in term of feeding habits (Bogliani *et al*., 1990). Nevertheless, the species is known for showing a wide spectrum of feeding and foraging habits across its range (see Cramp, 1985 for a review), so that data from different breeding areas are strongly needed.

The present note extends the knowledge of the species' diet with a contribution concerning the population nesting in the Po Delta, with an analysis of prey items from pellets collected in a colony located in a fish farm.

STUDY AREA AND METHODS

Fieldwork was conducted in a fish farm of the Po Delta (45°09’ N, 12°20’ E - 44°47’ N, 12°24’ E), during a wider project aiming at monitoring breeding waterbirds in the north-western Adriatic wetlands. Apart from the Po River and its branches, the Po Delta is characterized by several shallow brackish lagoons separated from the mainland by twenty-four fish farms and by thirty barrier islands. Large areas of agricultural land are present, whereas anthropic presence is scarce. In a 5-km radius around our study colony, agricultural lands account for 50% of the whole area, fish farms for 35%, Po River course for 8.6%, open lagoon for 1.7% and urban areas for 1.6%. In addition, there are

ditches for tens of kilometers. The community of breeding gulls and terns of the Po Delta is one of the largest in the Mediterranean, with ca. 7,000 pairs in 2015–2018 (Valle & Verza, 2020). In the last decade, 200-600 Gull-billed Tern pairs were found in the Po Delta (Valle & Verza, 2020). Due to its importance for birds, the area is listed as a Special Protection Area (IT3270023 – Delta del Po) under the European Union 147/09 Birds Directive. As an inexpensive and non-invasive way to monitor tern diet, we collected regurgitated pellets during early chick phase (June 11st 2018), during a visit aimed at assessing hatching success of a colony of 380 pairs. We analyzed composition of 60 grams of pellets. These pellets were shredded using entomological tweezers, yielding 445 fragments attributable to a defined taxon (corresponding to 45% of the total mass of pellets examined). The number of food items was estimated on the basis of singular or paired body parts of preys. Simpson's diversity index was calculated in order to compare our population with those of other breeding areas (Simpson, 1949).

RESULTS

Four hundred and forty-five prey items have been identified from 60 grams of pellets (Tab. 1). The main prey was invertebrates (403 items), whereas vertebrates accounted for only 9,4% of prey items. Among invertebrates, the majority were insects (50,8%, mainly *Orthoptera*: 22,7%) (Fig. 1). Mole Cricket *Gryllotalpa gryllotalpa* was the most frequent species found in pellets, totalling 46 items (10,3% of all items). Among insects, the remaining items are distributed among other bush crickets (*Ensifera*) and grasshoppers (*Caelifera*) (12,4%) and *Scarabeidae* coleopters (18%), with *Cetoniinae* and *Melolonthinae* subfamilies accounting for 10,6 and 7,4% respectively. Forty-five fragments (10,1%) were not ascribable to a determined insect species. Crustaceans accounted for 22% of prey items, Red Swamp Crayfish *Procambarus clarkii* being the only species of this taxon. Molluscs accounted for 17,8% of prey items, mostly the gastropod *Tritia neritea* (16,2%), and the rest being bivalves (1,6%). Among the fragments attributable to vertebrates (9,4%), the abundance of tibio-fibulae and femurs of anur amphibians, probably attributable to the genus *Rana* (L., 1758) or more likely *Pelophylax* (Fitzinger, 1843), stands out.

In comparing our data to other breeding areas (Tab. 2), the Simpson's diversity index shows relatively high value (0,35), confirming a diversified diet for Gull-billed Terns foraging in the Po Delta.

DISCUSSION AND CONCLUSIONS

The main finding of this study is that Gull-billed Terns breeding in the Po Delta follow a varied diet comprising different taxa. There is a good correspondence between the different habitat

representation within the foraging area of our colony (in a 5 km radius around the colony) and the type of prey. In the Po Delta, Gull-billed Terns hunt close to the colonies, up to 4-5 km far away, mostly on ditches, small channels and cultivated fields (Grussu *et al*., 2019). Fish farms, ditches and agricultural lands are well represented within the foraging range of our colony and host main prey types of Gull-billed Terns: respectively *Gasteropoda*, Red Swamp Crayfish and Mole Crickets (Figg. 1-3). The prevalent predation of *Orthoptera* observed in the Po Delta, which alone accounted for 22,7% of prey items, is reasonably linked to the high prevalence of Mole Crickets, which also are the main prey of other insectivorous birds in the study area, such as the Eurasian Hoopoe *Upupa epops* (Dissette *pers*. *comm*.). In other areas, Mole Crickets are far less represented in the diet of Gull-billed Terns: for example, in Alyki (Greece) they accounted only for 2,6-3,7% despite the total *Ensifera* crickets granting a 50-90.3% of the total prey items in the two colonies studied (Goutner, 1991). Red Swamp Crayfish high frequency in pellets is a finding that deserves a separate comment (Fig. 2). Though non-native species play a major role in the loss of native species, also favorable effects have been reported as for the Red Swamp Crayfish, which represents a food resource for many animal species, including fish, reptiles, birds and mammals (Correia, 2001). Birds preying on the Red Swamp Crayfish are numerous and include many waterbird species (Giordano & Battisti, 2023). We have no explanation for the low representation of fish in the diet of our population, given the common presence of these in the brackish water shallows surrounding the nesting site. We rarely observed Gull-billed Terns feeding in these large shallows, despite them being at close distance from the colony. A similar behaviour has been reported for the nearby population of the Valli di Comacchio wetland (Bogliani *et al*., 1990). On the other hand, fish are rarely a relevant quote of prey items for the species (see Cramp, 1985 for a review).

Diet pattern of Gull-billed Terns of the Po Delta is congruent with the feeding habits of the species reported for the species worldwide (Tab. 2). Prey types widely vary across the world, due to the wide variety of foraging habitats, but Gull-billed Terns mostly feed on terrestrial vertebrates and invertebrates (see Cramp, 1985 for a review). The relative frequency of the various taxa in the diet of the Gull-billed Terns of the Po Delta lies between the average values of the range reported in the literature for worldwide populations, with the exception of molluscs, which is the highest up to found (Tab. 2). The reason for this probably lies in the high frequency of the species found in the pellets of Gull-billed Terns (*Tritia neritea*) in the waterbodies surrounding the colony under study. Birds were seen pecking these *Gasteropoda* directly from the water, while resting on the shores of the colony site (*pers. obs.*). Likewise, the difference between the diet of our study in the Po Delta (where Gull-billed Terns feed mainly on *Orthoptera*) and that found in the nearby (50 km) Valli di Comacchio wetland (where the species fed almost exclusively on lizards: Ruin Lizard *Podarcis sicula*; Bogliani

et al., 1990) is striking and deserves further investigations. On the other hand, in other areas of the north-western Adriatic coastline, the species was reported foraging on a wide spectrum of preys, including both and invertebrates, using terrestrial habitat, with a sex differences in foraging behavior (Scridel *et al*., 2023).

These difference in food type patterns between the Po Delta and some of the other nesting areas should not be surprising, since it is in accordance with the known flexibility of the species in terms of both feeding and foraging habits (see Cramp, 1985 for a review). Significant differences in both prey types and hunting/fishing environments have been widely reported, both within different parts of the world and at the level of colonies located a short distance from each other (Tab. 2). This relates both to differences in the type of the available habitats within the foraging range of the species (< 10 km; Fasola & Bogliani, 1990) and differential exploitation of the latter due to inter- and intra-colony variations (Goutner, 1991 and Quinn & Wiggins, 1990 respectively). In addition, some populations have shown a much more specific prey selection, such in the nearby Valli di Comacchio wetland (lizards *Podarcis sp*.; Bogliani *et al*., 1990) or in Greek wetlands (crabs *Carcinus sp.*; Goutner, 1991). Some populations in Spain (Fuente de Piedra) were even reported being almost exclusively (>99%) specialized on insects (Sanchez *et al*., 1991). Anyway, comparisons must be taken with great caution since over- or under-estimates may result from the different methods used, some of which were reported over-estimating the proportion of insects (Bogliani *et al*., 1990). Another limitation in comparing studies conducted in different nesting areas is the significant difference in results produced between indirect methods (such as the analysis of prey remains found around the nests) and direct methods (identification of prey brought by adults to chicks), as demonstrated by Bogliani *et al.* (1994), for another tern species, the Little Tern (*Sternula albifrons*).

This study declares two main limitations. The main one resides in the nature of some of the prey items (such as crayfish claws and mole cricket forelegs), which are unmistakable and very tough, resulting in a possible overestimation of numbers in the pellets. This can be generalized to the whole spectrum of prey ingested by chicks: the digestion rate of different prey and therefore the amount of remains found in pellets can change. For example, a prey with many soft parts and few indigestible parts will leave fewer remains and will risk being underestimated in the diet estimate compared to a prey with a skeleton or chitinous covering (Bogliani *et al.*, 1994). A second limitation is that the latter were collected on a single visit, with the consequent possible bias related to possible changes in prey availability in the following weeks.

In conclusion, the present work provides the first data on the feeding habits of the Gull-billed Tern breeding in the Po Delta, showing a predominance of insects in the bird's diet, but with

significant shares of crustaceans and molluscs and to a lesser extent, amphibians. This confirms the known flexibility of the species in adapting to the trophic availability of the nesting area.

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Fig. 1. Gull-billed Terns with a Great Green Bush Cricket *Tettigonia viridissima* (left bird) and a Mole Cricket *Gryllotalpa gryllotalpa* (right bird); Po Delta, June 11th, 2018. / Sterne zampenere con un esemplare di Cavalletta verde *Tettigonia viridissima* (a sinistra) e Grillotalpa *Gryllotalpa gryllotalpa* (a destra), come imbeccata; Delta del Po, 11 giugno 2018.

Fig. 2. Gull-billed Tern with a Red Swamp Crayfish *Procambarus clarkii*; Po Delta, May 25th, 2023. / Sterna zampenere con un esemplare di Gambero rosso della Lousiana *Procambarus clarkii*, come imbeccata; Delta del Po, 25 Maggio 2023.

Fig. 3. Gull-billed Tern with a Dark Bush-Cricket *Pholidoptera grisoaptera*; Po Delta, June 11th, 2018. / Sterna zampenere con un esemplare di Folidottera cinerea *Pholidoptera grisoaptera*, come imbeccata; Delta del Po, 11 giugno 2018.

Tab. 1. Diet of Gull-billed Terns *Gelochelidon nilotica* on Po Delta (NE Italy), according from pellet analysis at early chick stage (June 11st 2018). Numbers/percentages refer to a total of 445 prey items. / Dieta della Sterna zampenere *Gelochelidon nilotica* nidificante nel Delta del Po, in base all'analisi delle borre raccolte nel periodo immediatamente successive alla schiusa dei pulli (11 giugno 2018). I numeri e le percentuali si riferiscono a un totale di 445 prede.

Taxa/Family/Genus/Species	Number	Percentage
INSECTA	226	50,78
Coleoptera	80	17,98
Scarabeidae	80	17,98
Cetoniinae	47	10,56
Melolonthinae	33	7,42
Orthoptera	101	22,7
Ensifera	90	20,22
Gryllotalpa gryllotalpa	46	10,34
Tettigoniidae	44	9,89
Caelifera	11	2,47
Acrididae	11	2,47
Unidentified *Insecta*	45	10,11
CRUSTACEA	98	22,02
Procambarus clarkii	98	22,02
OSTEICTHYES	5	1,12
AMPHIBIA	37	8,31
Anura	37	8,31
GASTEROPODA	72	16,18
BIVALVIA	7	1,57

Tab. 2. Diet of Gull-billed Terns *Gelochelidon nilotica* on different breeding sites worldwide. Percentage of prey items are reported. / Dieta della Sterna zampenere *Gelochelidon nilotica* nidificante in diverse aree del mondo.

Taxon	*Insecta*	*Crustacea*	*Actinopterygii*	*Amphibia*	*Mollusca*	*Aves*	*Reptilia*	*Mammalia*	Simpson's D
ITA1	50,8	22,0	1,1	8,3	17,8	0	0	0	0,35
ITA2	17,1	0	11,4	1,6	0	0,3	66,9	2,7	0,49
ESP1	78,5	13,0	0,5	6,5	0	1,5	0	0	0,64
ESP2	18,1	69,2	6,5	3,2	0,1	0,4	2,5	0	0,52
ESP3	99,5	0	0	0,1	0,3	0,1	0	0	0,99
ESP4	52,8	42,8	0,9	3,5	0	0	0	0	0,46
GRC1	98,0	0	0	0	1,1	0,3	0,3	0,3	0,96
GRC2	39,3	53,3	1,2	5,8	0,4	0	0	0	0,44
GRC3	89,0	5,9	0,2	3,9	0,3	0	0,4	0,3	0,80
UKR	42,0	0	25,0	24,0	0	1	7,0	1	0,30
MOR	51,4	0	0	48,6	0	0	0	0	0,50
EGY	97,9	0	1,9	0	0	0,1	0,1	0	0,96
RUS	48,0	11,0	0	0	0	0	26,0	10,0	0,32
FRA	66,3	0	0	16,6	0	0,2	0,2	0,2	0,47
DNK	48,0	17,0	9,3	9,3	0	7,4	8,4	17,8	0,32

DNK: Møller, 1982.EGY: Hering *et al.*,2021. ESP1: Bertolero & Rivaes, 2016. ESP2: Bertolero & Rivaes, 2016. ESP3: Sanchez *et al*., 1991. ESP4: Costa, 1984. FRA: Møller, 1982. GRC1: Goutner, 1991. GRC2: Goutner, 1991. GRC3: Goutner, 1991. ITA1: this study. ITA2: Bogliani *et al.*, 1990. MOR: Cabo & Sanchez, 1986. RUS: Borodulina, 1960. UKR: Zubakin & Kostin, 1977.