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Evidence suggests an opportunistic entomophagous diet of the White Stork *Ciconia ciconia* in Sicily during breeding and post-breeding periods

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Abstract - Insects are known to represent a critical part of the White Stork *Ciconia ciconia* diet throughout its breeding range. Yet, the composition of the diet in the storks breeding in the Mediterranean regions remains poorly explored. Here, we investigated the diet of a population of white storks from Sicily through pellets collected in 2003, 2007, and 2020. A total of 1,928 prey items were identified and classified into six categories. Insects dominated the diet in all years and represented 99.06% of the whole prey number. Two orders of insects were mainly consumed, namely Orthoptera, which were the most frequent prey, followed by Coleoptera. Within these, carabid beetles were dominant, followed by tenebrionids. Aiming to extend the study of the diet to the post-breeding period, we carried out direct observations on migratory Storks in September 2021, during the migration period. In this period, White Storks were observed feeding in arable lands with high concentration of small crickets *Grylloderes brunneri*. Altogether, our study provides new insights on the diet of White Storks in the Mediterranean range and highlights how conserving areas that support high diversity of insect species may also favor organisms at higher levels of the trophic chain.

Keywords: breeding areas, pellets, pre-migratory habitat, *Grylloderes brunneri*

INTRODUCTION

The population of the White Stork *Ciconia ciconia* in Sicily has largely increased over the last 150 years (Massa et al. 2021). Their first nest was recorded in the 1990s, and since then, the species has undergone a regular demographic growth (Surdo 2019, Zafarana et al. 2020) probably due to the immigration of individuals belonging to the Tunisian population, recorded as increasing by Azafzaf (2002). This species is considered a generalist and opportunistic predator and its diet has been well documented throughout its distributional range in Europe (Mužinić & Rašajski 1992, Antczak et al. 2002, Tsachalidis & Goutner 2002). White Storks feed upon a wide range of prey including invertebrate and vertebrate species (Melendro et al. 1978, Antczak et al. 2002, Kosicki et al. 2006, Cheriak et al. 2014, Hamadi et al. 2021). Earthworms, orthopterans, coleopterans, and small mammals (predominantly voles in eastern Europe) seem to be primary food resources throughout the

breeding range of this bird species to the point that invertebrates' abundance may indirectly affect the population dynamics of the White Stork (Ferreira et al. 2019). Despite this consistent bulk of studies, limited quantitative data is available on the White Stork diet in its Mediterranean range. The use of pellets in the study of the White Stork diet may produce biases, because some prey types may not leave identifiable remains (Lázaro 1982, Mužinić & Rasajski 1992), but it remains a valuable tool for quantitative analysis. The present study aims to contribute to fill the knowledge gap about the species' diet in Mediterranean regions by reporting pellets contents from a breeding population in Sicily and merging this information with field observations of foraging preferences during the migration period.

MATERIALS AND METHODS

Pellet analysis

Four breeding sites of White Storks have been monitored for pellet collection in Sicily over the years, namely in 2003 (Lentini Lake, Catania, 9 pellets), in 2007 (Gela plain, Caltanissetta, 25 pellets; Catania plain, Ponte Barca, Paternò-Catania, 1 pellet) (Zapparrata 2008), and in 2020 (Trinità reservoir, Trapani, 19 pellets) (Fig.1). All observations were carried out during the breeding season (June-July). Overall, 54 pellets have been collected under the nests sited on the top of electricity pylons. The collected pellets were disaggregated in the lab, their content identified using a stereomicroscope and compared with material from entomological collections. Reptiles were identified through the presence of scales and bone remains. Insect fragments were identified at the species level by comparison of the chitinous pieces and with species commonly present in the study areas (Rizzo & Massa 1995, Massa et al. 2012, Sparacio 1995, 1997, 1999). Every mandible was paired with its partner, and each head, fragment of legs and aedeagus were isolated, so that it was possible to count the total number of specimens in each pellet. Although many fragments remained unidentified, identification was possible in most cases. Prey item remains were identified to the lowest possible taxonomic level and then the minimum number of individuals (MNI) was quantified for each prey taxon. We estimated MNI by counting the number of fragments/items recovered in each pellet corresponding to different individuals of a same given prey taxon (Di Palma & Massa 1981). We performed a $\chi 2$ test to verify whether different sites varied in their relative proportions of prey groups.

Field observations

During the autumnal migration period (between 4 and 14 September 2021), we carried out observations on the feeding behavior of migrating White Storks in locality Ummari (Trapani). Observations were carried out through field scopes, specifically a Leica and a Swarovski 10×40 binoculars, a 20-60×80 Swarovski telescope, and a camera Canon EOS 7D provided with a 150-600 mm tele-objective. During the field observations at Ummari, we obtained an estimation of crickets *Gryllodères brunneri* abundance through visual counts, assessing the number of individuals per square meter during each visit over three different areas of about 100 m^2.

RESULTS

Pellet analysis

The most frequent items in the storks' pellets in Sicily resulted to be insects (Table 1). Overall, among 1,928 identified prey items, insects amounted to 99.06%, with orthopterans (60.3%) and coleopterans (38.6%) being the most abundant prey. The proportions of Orthoptera and Coleoptera differed significantly among sites ($\chi^2_{0,0001} = 822.6$). The three sites of eastern Sicily show a prevalence of Orthoptera compared to the site of Western Sicily, where Coleoptera were the main prey items.

Observations in the field

In the days between 4 and 14 of September at Ummari (Trapani) a variable flock of 15-50 White Storks was observed feeding on the ground. Using the telescope, we were able to confirm that they were collecting and

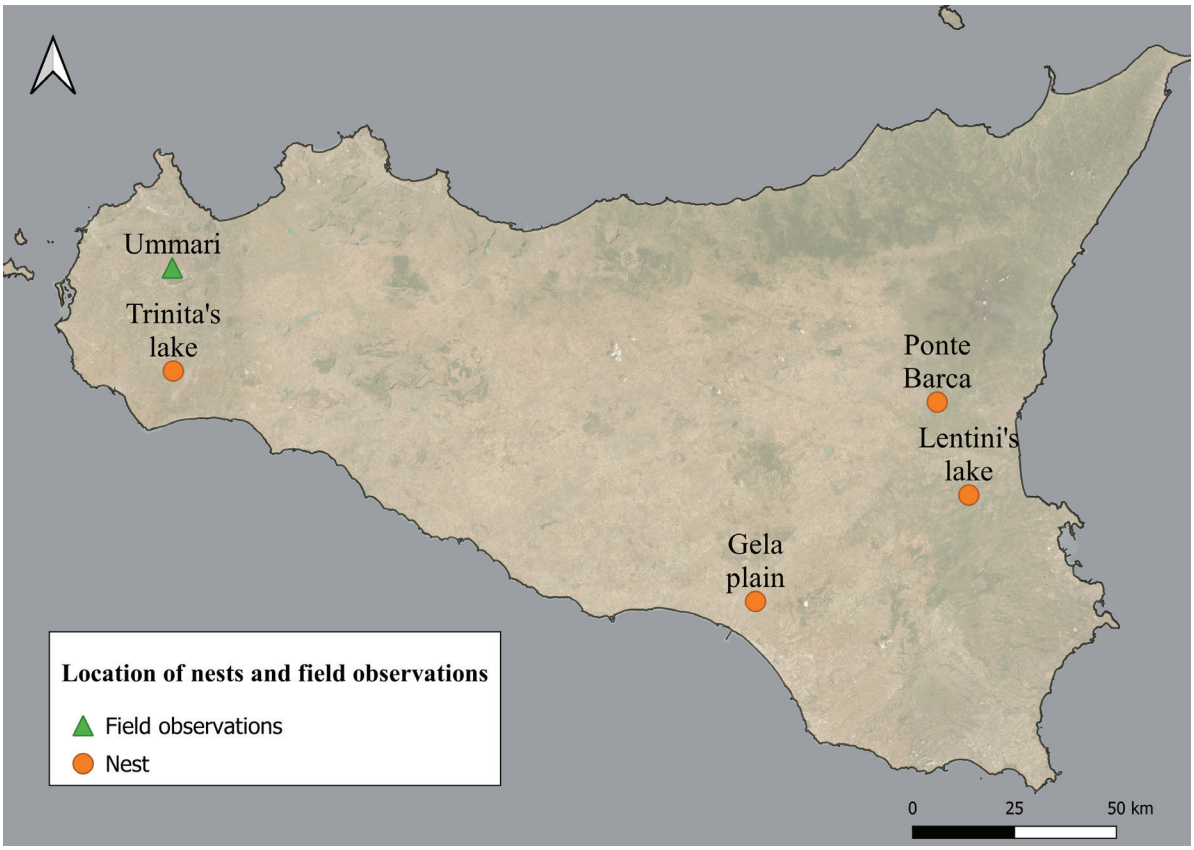

Figure 1. Distribution map of nests and pellets and the localities where migratory Storks were observed feeding on *Grylloderes brunneri*.

eating huge numbers of *Grylloderes brunneri* (Riggio, 1888), a cricket with a summer-autumn phenology and population size known to strongly fluctuate with some periodical gradations (Fontana & Massa 1999, Sarà et al. 2014). Specifically, on September 4th, in a field previously sown with wheat – an area of ca. 100 ha – *G. brunneri* were very abundant and 50 White Storks were found feeding on them (P. Lucido, B. Barbera, pers. comm.). Later, on September 8th, 39 White Storks were observed in the same area feeding on *G. brunneri*. We estimated more than 50 crickets per square meter. Among the White Storks, one ringed individual was observed with a colored ring (code W0044) that allowed us to identify its Slovenian origin. Interestingly, below an electricity pylon a carcass of a White Stork was found (dead for electrocution; see Zafarana & Barbera 2016), which was covered by *G. brunneri*, opportunistically feeding on the carcass. Finally, on September 14th, the number of *G. brunneri* declined noticeably (less than one individual per square meter) and only 14 White Storks were observed flying towards another close-by field.

DISCUSSION

We investigated the White Stork diet in a Mediterranean population in Sicily during the breeding season. Analysis of the pellets revealed that almost the entirety of the identifiable prey items are insects, with Orthoptera and Coleoptera orders being the most abundant, but that in the eastern sites of Sicily there was a prevalence of Orthoptera while Coleoptera where the main prey in the Western site. Additional field observations during the migration

Table. 1. Prey items in the pellets of White Storks in Sicily identified to the lowest possible taxonomic level and quantified as the minimum number of individuals (MNI). Prey items are reported both per location and in total.

Class and Order	Family	Prey	MNI All localities (Pellets=54)	MNI Trinità (Pellets=19)	MNI Lentini (Pellets=9)	MNI Gela's (Pellets=25)	MNI Ponte Barca (Pellet=1)
Mammalia Rodentia		unidentified	1			1	
	Muridae	*Apodemus sylvaticus*	1		1		
	Cricetidae	*Microtus nebrodensis*	2			2	
Aves		unidentified	1			1	
Reptilia Squamata	Scincidae	*Chalcides ocellatus*	1	1			
Insecta Coleoptera		**Total**	**745 (38.6%)**	**447 (94%)**	**39 (19,9%)**	**251 (20,2%)**	**7 (43,7%)**
	Carabidae	unidentified	142	17	23	99	3
		Chlaenius sp.	2	2			
		Carabus morbillosus	7	3		4	
		Scarites sp.	1	1			
		Percus sp.	20		4	16	
		Titomus calydonius	1				1
		Campalita maderae	2		1		1
	Cerambycidae	unidentified	1			1	
	Dytiscidae	*Cybister lateralimarginalis*	4	4			
		Dityscus sp	5		4	1	
	Hydrophilidae	*Hydrophilus* sp.	7	6			1
	Scarabaeidae	unidentified	46			45	1
		Onthophagus sp.	91	52		39	
		Copris sp.	16	16			
		Copris cavolinii	1	1			
	Geotrupidae	*Geotrupes spiniger*	13	13			
		Geotrupes sp.	25	25			
		Thorectes intermedius	59	59			
	Cetoniidae	*Aethiessa floralis*	1			1	
	Dynastidae	*Pentodon* sp.	3	3			
		Pentodon punctatus	17	1		16	
	Crysomelidae	*Timarcha* sp.	4			4	
	Buprestidae	*Capnodis* sp.	1	1			
	Tenebrionidae	unidentified	207	184	4	19	
		Tentyria sp.	5		4	1	
		Pimelia grossa	1			1	
		Alphasida sp.	3	2		1	
	Brachyceridae	*Brachycerus* sp.	19	17	2		
	Curculionidae	unidentified	5	5			
	Silphidae	unidentified	36	35	1		
Insecta Orthoptera		**Total**	**1177 (60.3%)**	**27 (5,7%)**	**156 (79,6%)**	**985 (79.4%)**	**9 (56,3%)**
		unidentified	1085		153	924	8
	Tettigoniidae	*Decticus albifrons*	47	2		45	
		Platycleis sp.	5	3	1	1	
	Acrididae	*Aiolopus strepens*	1	1			
		Aiolopus sp.	5	5			
		Oedipoda sp.	12	12			
		Chorthippus sp.	3	3			
		Calliptamus barbarus	1		1		
	Gryllotalpidae	*Gryllotalpa quindecim*	3			3	
	Gryllidae	*Grylloderes brunneri*	1	1			
Insecta Hemiptera	Pentatomidae	*Carpocoris* sp.	1			1	
Insecta Hymenoptera		unidentified	1		1		
Arachnida		unidentified	1			1	
Gastropoda Pulmonata		unidentified	11			10	1
Plants			remains	remains	remains	remains	remains
		Total prey number	1928	475	196	1240	16

period highlighted the importance of local high abundance of insects, and in this specific case of *Grylloderes brunneri* for migrating White Storks in Sicily.

The absence of fish and amphibian residuals in the pellets may be due to their rapid digestibility (Kwieciński et al. 2017), as it has been confirmed by observations of adults on the nest sites with fish, frogs and snakes. However, fish scales or amphibian bones were not found inside the pellets; this could also depend on the relative rarity of these classes of animals in the arid zones of Sicily. Overall, the most abundant identifiable prey were insects (99.06%), whose predation likely depended on the local abundance of some families or species. The presence of many coprophagous Scarabaeidae and Geotrupidae (251, 13%) suggests the search for these insects in rangeland, inside the dung of grazing cows or sheeps. Additionally, the high frequency of occurrence of grasshoppers (60.3%) indicates a preference of Storks for this order of insects, probably for their high digestibility and fat and protein content (e.g., Kinyuru et al. 2009).

In agreement with what was found by Tsachalidis & Goutner (2002), the proportions of orthopterans were highest in dry habitats, with lower proportions in lakes, rivers while the relative proportions of coleopterans varying gradually in rivers, lakes and dry habitats. Vrezec (2009), Orłowski et al. (2018) suggested that a diet mainly based on Coleoptera reduces the breeding success, compared to a diet with a prevalence of Orthoptera. Hence, future studies should aim at investigating if differences in diet composition in these eastern and western breeding populations are linked to differences in breeding success.

Insects are clearly an important prey of the White Storks, both in their breeding, migrating and wintering ranges, but their role in the diet and the proportion of the different taxa vary vastly (Cramp 1977, Glutz von Blotzheim & Bauer 1987, Sackl 1987, del Hoyo et al. 1992). Much data has been collected in Hungary in April-July and most prey resulted to belong to Orthoptera (mainly *Gryllotalpa* and *Gryllus*), Coleoptera (mainly Hydrophilidae and Carabidae), small mammals and amphibians; other diet data collected in spring in Germany list earthworms, snails, insects (mainly *Melolontha* and grasshoppers), mice and shrews, while in summer more Orthoptera and other insects (mainly Carabidae) prevailed (Cramp 1977). Coleopterans and orthopterans have also been found to constitute a favored prey for the White Stork in many parts of its range, including Poland (Pinowska & Pinowski 1989, Pinowska et al. 1991, Kosicki et al. 2006, Zbyryt et al. 2020), Hungary, former East Prussia (Rekasi 1989), central Balkans (Mužinić & Rašajski 1992), Algeria, Tunisia and Israel (Dallinga & Schoenmakers 1989, Boukhemza et al. 1995, 1997, Fellag 2006, Boukhtache 2009, Cheriak et al. 2014, Sbiki 2016). Large and profitable species reported in the diet of White Storks include Tenebrionidae, Carabidae, Scarabaeidae (Boukhemza et al. 1995, Tsachalidis & Goutner 2002, present study), Hydrophilidae (Barbraud & Barbraud 1997) and Silphidae (Schierer 1962). These studies suggest that insects are more frequent in the diet of White Storks in the southern areas of their breeding range, where the abundance of grasshoppers is high (Alonso et al. 1991, Rékási 2000, Sachalidis & Goutner 2002, Vrezec 2009, Massa et al. 2012), a notion strongly supported by our study.

Local high density of *Grylloderes brunneri* supported the foraging activities of a large group of White Storks in Sicily. The importance of *Grylloderes brunneri* as favored prey during the pre-migratory season of the Lesser Kestrel *Falco naumanni* has been previously highlighted by Sarà et al. (2014). Interestingly, a similar case was observed for an Egyptian Vulture *Neophron percnopterus*, equipped with a GPS; the GPS signal allowed the researchers to observe the bird preying on *G. brunneri* for three days (10-12th September 2021) in a locality not far from that where White Storks were observed, in a plough field previously sown with wheat (A. Brucoli, pers. comm.). Thus, the huge numbers of these crickets could represent an important opportunistic prey for

migrating birds, including White Storks. Altogether, the present study confirms the entomophagous diet of the White Stork during breeding and autumn seasons in central Mediterranean and highlights the importance of conserving areas that support high diversity of insect species. Arable lands provide remarkable feeding opportunities not only for the White Stork but also for many other birds; as such, management of these areas should be planned considering not only their agricultural value, but also the conservation relevance.

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