Chancellor, R. D. & B.-U. Meyburg eds. 2004
Raptors Worldwide
WWGBP/MME

On the insect diet of Eleonora's Falcon *Falco eleonorae* and its importance for coloniality[1]

Dietrich Ristow

ABSTRACT

Pellets near nests and insect fragments in nests of Eleonora's Falcon *Falco eleonorae* in Crete were collected and used to analyse the insect diet. Results are compared with other respective data across the species' range. The hunting behaviour on small and large insects in flight is described and discussed as to its importance for communal feeding, gregarious roosting, and coloniality in falcons.

INTRODUCTION

Several small falcon species feed on insects to a large extent (del Hoyo *et al.* 1994). But also large falcons such as the Peregrine *Falco peregrinus* catch and eat insects occasionally (Rockenbauch 2002). Eleonora's Falcon *Falco eleonorae* is an aerial predator of fairly large size which feeds on insects in its wintering quarters in East Africa and the adjoining Indian Ocean islands and primarily on insects in its breeding range in the Mediterranean basin and western Atlantic during spring till July/August. At this time of year the diet gradually shifts to small migrant birds caught above the sea, close to the breeding colonies on cliffs (Walter 1979). Some late passerine spring migrants are preyed upon, too, as is implied by bird remains in seven out of 26 stomach contents obtained during May-July (Vaughan 1961).

When analysing the causes for secondary or inadvertent poisoning in this species (Anonymous 2002; Ristow 2001), it is essential to have a reference list on its diet. There are quite a few lists on captured bird prey in autumn - e.g. Ristow *et al.* (1986) for Crete, Spina *et al.* (1987) for Italy, Mayol (1976) and Araujo *et al.* (1977) for Spain, Walter (1979) and Clark (1981) for Morocco. But there is not a similar status of knowledge on insect diet which is reviewed in Tables 1+2. These data were extracted from the literature given at the end of

[1] This contribution represents part 26 of a series on Eleonora's Falcon

this paper and from personal communications. They represent a compilation of scattered and unsystematically obtained data; the best list was published by Araujo *et al.* (1977). This contribution is no marked step forward, but aims to stimulate the discussion about the social aspects of bird and insect hunting.

MATERIAL AND METHODS

The pellet study was carried out in a large colony of Eleonora's Falcon on an islet off Crete in 1997, general prey study at nests in Aug.-Oct. 1988. Perch sites are typically a few metres away from the eyrie. Below them, up to twenty pellets may be piled up. Some fall apart like chaff when touched, others have already fallen apart when vomited, and several digestive stones are found at the site. Complete pellets from one site were carefully collected into a small plastic bag and a paper slip was added with a note about the number of pellets containing feathers, beetles, ants, cicadas, or a mixture of them, as could be judged from pellet surfaces. Except for those with feathers, pellets tended to fall apart during transport later on. The analysis showed that the digestive stones did not mill ant or beetle fragments to powder, whereas remains of moths, butterflies and dragonflies were completely digested.

RESULTS

As there was no rain in May-July 1997, the results refer to this whole season. Only about 10% of the pellets contained uniform prey types, whereas usually they consisted of some mixture. Thus

- 21 with bird remains
- 72 with beetles
- 119 with cicadas
- 132 with ants

in a total of 205 pellets were found. A few contained grasshoppers (Saltatoria); in two pellets there were no wings amongst the ants. The beetle fragments could be determined to a somewhat better accuracy in a few cases:

Coleoptera: Carabidae, *Carabus sp., Calosoma sycophanta*

- Dytiscidae *Agabus sp.*
- Staphylinidae
- Elateridae *Elater ferrugineus*
- Buprestidae at least three species; Calcophora
- Scarabeidae
- Geotrupinae
- Melolonthinae
- Cetoniinae at least two species; *Potosia sp.*

As a supplement to the above , eight stomach contents of dead falcons from the same colony are given. Although the carcasses were found in September 1999-2001, the date of death was estimated to be in July. Four stomachs were full with cicadas, one with Buprestidae, one with dragonflies, and two were empty. Stomach contents were more uniform than pellet contents.

From August onward fresh pellets contain feathers primarily. During incubation of the eggs, the female plucks birds, brought by the male, in the vicinity of the nest. When the chicks have hatched, bird pluckings can be collected in the eyrie. Only very few insect fragments are found in the nests then, and their numbers decline with season (Column k Table 3). These insects

Table 1. Review on insect diet of Eleonora's Falcon within its breeding range.

	Methods			
	Observation	Pellet	Item in nest	Stomach content
Odonata	X	X	X	X
Hymenoptera		X		X
Orthoptera	X	X	X	X
Cicada	X	X	X	X
Lepidoptera				
Zygaenidae	?*			
Papilionidae	X	X		
Nymphalidae	X		X	
Sphingidae		X	X	
Coleoptera				
Silphidae	?*			
Carabidae		X		X
Dytiscidae		X		
Staphylinidae		X		
Elateridae		X		
Aliculidae	X**			
Buprestidae	X	X		X
Scarabeidae		X	X	X
Geotrupinae	X			
Melolonthinae	X	X		X
Cetoniinae		X		
Tenebrionidae	X	X	X	X
Curculionidae		X		
Formicidae	X***	X	X	
Formica	X			X
Camponotus				X
Messor	X			
Scolopendridae		X		

* The published observation on hawking behaviour lacks credibility.
** This includes an observation of one Kestrel (*Falco tinnunculus*) with the Eleonora's Falcons feeding on *Omophlus spp.* Naxos 17 May 1996 (D. Ristow).
*** This includes observations of 3-4 Kestrels with the Eleonora's Falcons feeding on winged ants near Bodrum on several days June 1981 (H. Tollemache).

Table 2. Complete review on the diet of Eleonora's Falcon during migration and in its wintering quarters. (O. Langrand pers. com., Ristow & Wink 1992, Walter 1979, Thorstrom & Rene de Roland 2000).

locusts (Orthoptera) in Egypt
insects and termites (Isoptera) in Somalia
termites in Tanzania
small birds, insects and Coleoptera (Cetoniinae) in Madagascar
dragonflies along the mountain ridges on Mauritius (M. Nicoll)
two stomach contents - one empty, the other one with a few insects – on the Seychelles 1 Nov. and 17 Nov. 1972 (C. B. Frith)

are caught in the near vicinity of the colony, as is implied from injured but live locusts in the nests. Anyway, the importance of these insects for chick rearing is negligible in comparison to the bird biomass. In particular, the percentage of Coleoptera during summer-to-autumn drops markedly. But after fledging, when the young become independent, insect food caught on the mainland may become important for them prior to departure for east Africa and Madagascar (Clark 1981).

Table 3. The number of insect prey items (i) in relation to number of bird pluckings (j) collected in Crete at nests of Eleonora's Falcons - n=20 and 40 nests in 1975 and 1988 respectively; k (per nest and ten days) is the calculated insect to bird ratio.

Season	a Odo	b Ort	c Nym*	d Sph*	e Col	f Cic	i ∑ a to f	j birds	k i:j:n x 10^5
I July '75		1							
II July					3				
III July		1	1	3		1			
sum July							10	60	833/3
III Aug '88	16	9	9	4	-	1	39	400	244
I Sept	12	12	2	2	-		28	1300	54
II Sept	1	4		1	-	1	7	1500	12
III Sept	2			1	-	1	4	2000	5
sum							78	5200	38/4

*10 of 12 Nymphalidae were *Vanessa cardui*, 9 of 11 Sphingidae were *Hyles lineata*.

DISCUSSION

As the above results and Tables 1&2 show, the status of knowledge on the insect diet in Eleonora's Falcon is unsatisfactory. Methods of investigation and systematic collection procedures have to be improved to assess the biomass of swarming in comparison to non-swarming insects as well as diet dependency on the natural cycles of these species'. A first step would be to do experiments on insect diet as a pellet study in a falcon rehabilitation centre. An increased effort is worthwhile doing as the following thoughts may indicate.

Eleonora's Falcon is usually unsuccessful when pursuing a bird above the land and quits hunting as soon as the prospective prey reaches the ground. Birds which are adapted to open country life such as wagtails, *Motacilla alba* and *M. flava*, or Blue Rock Thrush *Monticola solitarius* are uncommon prey in relation to their frequency at the breeding islets. Birds which are adapted to open air life such as Common Swift *Apus apus* and Alpine Swift *Apus melba* may even breed in colonies on islets together with falcon colonies. Examples of co-existence of such colonies over fifty years are known, although swift fledglings fall prey to the falcons in appreciable numbers. These observations imply that Eleonora's Falcon is not a skilful bird hunter from its stature. One may continue along this line of thought, that adaptation to avian prey and islet life occurred later during the species' evolution, and that flying insects had originally formed its basic food. Ecological studies in relation to avian prey

would then bear the potential to understand this exceptional, specific behaviour whilst insect studies would be a key towards common behaviour with related falcon species. Obviously, in Eleonora's Falcon studies to date, the bird aspect was the favourite ecological topic of the researchers. But, what could be learnt from insect studies?

Chicks grab insects such as locusts with one talon like adults (and not with the bill at first), stand and keep balance on the other talon, and can bite off and swallow piece by piece at a much earlier age as compared to the time when they are able to dismember a bird prey deposited in the nest by a parent. Also, an adult never takes a small insect such as a winged ant in the air by the bill. Eleonora's Falcon approaches such small prey in casual flight at altitudes of typically above 50m, interrupts wingbeat, throws the body upward so that a talon can gently take the insect; and right away the falcon continues its normal wing beat or gliding flight, the head bows down, and the falcon quickly swallows its prey. It is this mode of insect hawking which can be observed when fifty or more Eleonora's Falcons share an insect food source. Such gregarious hunting within an area of, typically, 500m diameter lasts 5-30 minutes until the flock dissolves. Large insects such as locusts are captured in a different way. The falcon flies at about 20m altitude above a vineyard for example, then it suddenly swoops down and takes the locust near the tip of the vine or even between the rows of vines; at the last moment the falcon can perform a sudden line of flight correction to grab the flying prey with its talons in spite of its escape manoeuvres; and right away the falcon swings up to its former altitude and, after having lost speed, sails in a circle with a few wingbeats, while it repeatedly bows the head to the talons and eats its prey piece by piece. At such a food source, typically only half a dozen Eleonora's Falcons may be seen together. At some distance of course, the observer can see the falcons' flight behaviour only and not the insect prey. These two modes of hunting behaviour can be recognized at more than a kilometre's distance. The former mode, as it is performed at higher altitudes, is more likely to be a signal for conspecifics to decide whether to join the exploitation of a food source. It may also be the stimulus to other bird species and *vice versa,* because Eleonora's Falcons are known to feed communally on flying insects with Hobby *Falco subbuteo* (Ristow 2004), Red-footed Falcon *Falco vespertinus* (Hölzinger 1990; Balmer & Betton 2002), Amur Falcon *Falco amurensis* (Turner 1978), Sooty Falcon *Falco concolor* (Walter 1979), European Kestrel *Falco tinnunculus* (see footnotes in Table 1), and gulls (Ristow & Wink 1992).

In autumn, bird hunting above the sea close to the breeding colonies requires a much greater chasing effort per passerine than needed per insect, albeit a bird with its higher nutrional value is worth the increased effort. A single falcon has good chances to succeed on its own when attacking a passerine migrant above the sea. It is a disadvantage for the falcon individual when several conspecifics join the pursuit. Therefore, bird hunting near the breeding colony is competitive and cannot be a prime factor for coloniality in this falcon. Indeed, food piracy in colonies is common, and means an additional energy expenditure for the group of falcons involved.

Insect searching in falcons resembles the respective food searching

behaviour of other colonial birds to a large extent. In colonial seabirds, individuals may pick up a piece of food here and another one there during search flight, and conspecifics do not join in. Locations of food patches are unpredictable, and individuals have to cover great distances in foraging flight at sea. Once a food patch is spotted, it is more than what an individual can consume during the time span the food is available. Many conspecifics and even other seabird species join in the exploitation. Similarly, colonial vultures search individually for many miles to spot and later on share a carcass to be found at unpredictable locations, the carcass being larger than what an individual can consume. Even other bird species join in the exploitation. In the case of Eleonora's Falcon, the size of passerine prey is less than what an individual can consume in a single sitting. Similarly, in European Kestrels, a vole is less than an individual's daily ration. Gradation of voles to be exploited day for day at the same location, is no stimulus for them to breed colonially, so "gradation" of migrating passerines is unlikely to be such a stimulus either. Indeed, there is no colonially breeding falcon species which depends upon passerine spring migrants, and the Peregrine *F. peregrinus* which expoits this food source breeds solitarily on Mediterranean islands.

Along the same line of thought, insects on the mainland are far away from a falcon islet and form food patches at unpredictable locations. Eleonora's Falcons have been observed to depart for the mainland more than 30km from the breeding cliffs and stay away all day or longer, at the time of year when insects form their prime food. When nest spacing or colony size are taken as a measure for coloniality and various falcon species are compared, a rule becomes apparent: the more insectivorous a falcon species is, the higher is its degree of coloniality. Although not easily done, it would be of interest to investigate whether colony size (and clutch size) in Eleonora's Falcon depend on the availability of insect prey during April-July prior to the actual breeding season and whether the distribution range depends on small scale variation of daily weather during this season of year, so that large flying insects can form a reliable food source for such a large falcon. This falcon is too large to raise broods colonially by insect diet on the mainland. This domain belongs to smaller, colonially breeding falcon species which also require the small scale daily weather variations. All these falcon species are capable of defending the brood individually, communal defence reaction being restricted to the area outside the near-nest-vicinity and being of secondary importance for coloniality (Ristow *et al.* 1982).

These arguments support the hypothesis that insect diet is the primary factor and communal breeding is of secondary importance for social life. In Eleonora's Falcon, the isolated locality of a breeding colony is a communal roost site in the first place where foraging experience is shared. This interpretation implies that:

1. There should be communal roost sites on the mainland, too. Unfortunately, studies of roosting (telemetry) during April-July are lacking up till now. There is only some information about colony occupancy from a single breeding islet during this time of year (Ristow & Wink 1992), from which it is implied that substantial numbers of Eleonora's stay away from

colonies overnight, especially in June.

2. Communal roost sites should have the same social function in winter as the breeding sites do in summer. Unfortunately again, studies of roosting in Madagascar are lacking in Eleonora's Falcon, but there is a single observation that an Eleonora's Falcon joined a group of Sooty Falcons for roosting (Walter 1979). As to the other falcon species, communal roosting in the wintering area on the basis of insect food is known for Hobby, Red-footed Falcon (Cramp & Simmons 1980), and Lesser Kestrel *Falco naumanni*, the latter sometimes communal with Red-footed and Amur Falcons (Siegfried & Skead 1971; Colahan 1993).

The inter-dependency of insect diet and (breeding) coloniality can be noticed in birds of similar size as the falcons when comparing closely related species, e.g. the colonial Chimango Caracara *Milvago chimango* with the Yellow-headed Caracara *Milvago chimachima*, the semi-colonial Montagu's Harrier *Circus pygargus* with the Hen Harrier *Circus cyaneus* (del Hoyo *et al.* 1994; Clarke 1996), or, the colonial Rook *Corvus frugilegus* with the Carrion Crow *Corvus corone*: The more insectivorous species is the more sociable one in summer as well as in winter. Not being aerial predators to such an extent as falcons, these social birds have breeding colonies across a larger climatic range than colonial falcons do. Of particular interest in the Eleonora's Falcon context is the fact that the more insectivorous harrier, i.e. the Montagu's Harrier, is ancestral to the Hen Harrier (Wink in Simmons 2000).

ACKNOWLEDGEMENTS

Studies in the Aegean were carried out under permit of the Greek Ministry of Agriculture. F. Feldmann, W. Scharlau, and M. Wink did the plucking collecting with me in 1988. D. Erber kindly analysed the pellet contents.

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Dietrich Ristow
Pappelstrasse 35
D-85579 Neubiberg
Germany