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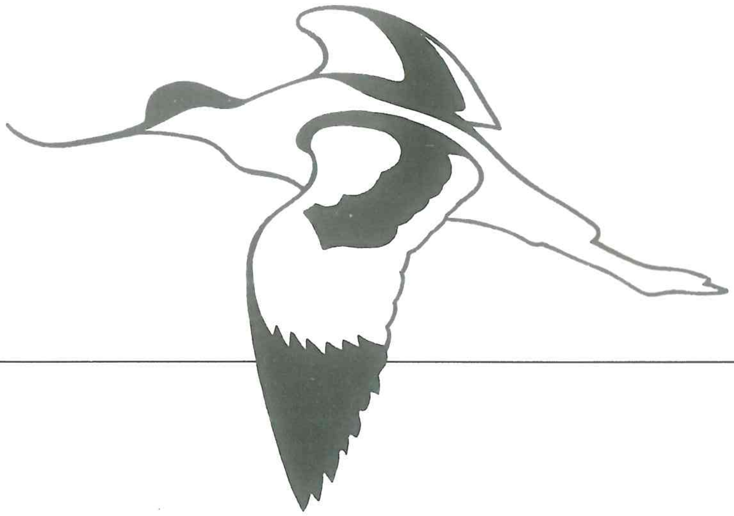

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The status and breeding biology of the Chough (*Pyrrhocorax pyrrhocorax* Linnaeus) in the Central Apennines-Abruzzo-Italy

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Abstract - The breeding biology of the Chough is little known in Italy. A number of research projects, started in 1992 in Abruzzo, confirmed the importance of this area for the species. The 633-899 breeding pairs were widespread in the larger massifs of the region and the presence of at least 2,000 birds was estimated. 55 breeding attempts from 1993 to 1995 produced a mean number of 2.40±1.26 SD fledgings per pair. In most cases the pairs bred in colonies. The breeding period began at the end of March and the young fledged up to the beginning of July with pairs at higher altitudes fledging later. Activity at the nest sites had its maximum at the nest-building stage of the breeding period, thereafter decreasing. Observations of mortality of newly fledged young and of interactions with other species near the breeding sites are reported. Competition with the Jackdaw (*Corvus monedula*) for nesting cavities is confirmed, resulting in the dominance of the Chough.

Introduction

The Chough (*Pyrrhocorax pyrrhocorax*, Corvidae) is widespread with a large Palearctic range and two small isolated populations in Ethiopia. In Western Europe it is patchily distributed (Farinha 1991, Guillou 1981, Lovari 1977, Monaghan 1989). An important decrease of the British populations was reported up to the 60's (Bullock *et al.* 1983, Monaghan 1989, Owen 1989b) probably due to a combination of factors including persecution and land-use change - particularly the decline of the traditional forms of farming (Bignal *et al.* 1989). Following the 1960's these populations stabilized. Negative trends were also confirmed for Italy and the other European countries (Farinha and Texeira 1989, Garcia Dory 1989, Orlando 1992, Thomas 1989), but in Spain there is still a flourishing population (Blanco *et al.* 1991, Blanco *et al.* 1997, Soler 1989). For these reasons the species is included in the Annex 1 of the 79/409/EEC Directive on the Conservation of Wild Birds. The species has been the subject of a large number of studies since the 1980's but detailed studies about its breeding biology are avaible only for the United Kingdom and Ireland (Bignal *et al.* 1987, Bullock *et al.* 1983). Only one study including some data about the breeding biology of the species has been conducted in Italy, in the Abruzzo National Park (Lovari 1977). The Stazione Ornitologica Abruzzese identified several areas of great importance for the Chough in the Central Apennines (De Sanctis 1995, Pellegrini *et al.* 1995). The present study focuses on the breeding biology of the species in central Italy, particularly concerning the choice of breeding site and reproductive success and defines the current status of this species. The latter will permit future evaluation of population trends and establish an important basis for the protective action necessary to comply with EC and National Legislation.

Study area

The breeding sites used for the statistical elaborations were located in 6 areas of the Central Apennines in the Abruzzo region: the Majella National Park (47 nests), Velino-Sirente Regional Park (28), Gran Sasso National Park (13), Sagittario Gorge (23), Abruzzo National Park (4) and S. Venanzio Gorge (2). Abruzzo is mainly mountainous with calcareous massifs that reach 2912 mt. The following enviromental situations are present in the areas frequented by the Choughs

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from 500 mt to 2912 mt a.s.l.: 500-800 mt. traditional farming with mosaics of olive-trees, cereals and vineyards, with secondary grassland pasture and woods with a prevalence of *Quercus pubescens*, *Ostrya carpinifolia* and *Fraxinus ornus*; 800-1700 mt beech-woods (*Fagus sylvatica*) and large secondary grassland pasture, with cereal and fodder farming. Above 1700 mt. there are large areas of primary grassland pastures. There are numerous valleys and gorges with several kilometres of rocky cliffs that offer ideal nesting sites for the species.

Methods

Breeding sites were located by surveying suitable areas from 1993 to 1995 during the reproductive season from April to July following the method used by Bullock *et al.* (1983).

We monitored the activity at the nests (expressed as number of visits per h) in 1996 at the colony of the WWF Oasis of the Sagittario Gorge (De Sanctis 1995). We recorded all visits to the nests irrespective of their purpose. We subdivided the breeding period in four stages: nest building, incubation, brooding (days 6-18) and late nestlings (days 28-40). For two days of each stage we monitored the same six nests simultaneously. All observations were conducted during days without rain and between 0950-1330 hours and lasted 120 minutes minimum. Data about features of the sites were collected through the Istituto Geografico Militare cartography (scale 1:25,000), using photographs and by objective field evaluations, and were subdivided according to Zuniga (1989). These data were not available for all nest sites. Data referring to the distribution and the number of breeding pairs were not collected in a uniform manner. For the Sagittario Gorge (De Sanctis 1995), Velino-Sirente massif, and the South part of the Gran Sasso massif detailed census was available while others estimates were based on observation of flocks at various periods of the year and on non-standardized observations of the breeding areas. In addition the Majella census (Pellegrini *et al.* 1995) was carried out using an indirect method (i.e. a direct census of sample cliffs – irrespective of the suitability for the Chough – to establish an index of the number of pairs per linear kilometre of cliff multiplied by the total kilometres of cliffs of the area). Although the latter method probably failed to estimate the number of pairs with great precision, it does have two important qualities: at first it permits an estimate of numbers in very irregular areas where a direct census is almost impossible due to inaccessible gorges and then it is easily repeatable. To estimate the numbers of pairs from counts of flocks we used the ratio of non-reproducing birds in the period April-June known for the colony of the Sagittario Gorge and for one colony of the Majella massif (35-60%) and that indicated by Lovari (1977) for the Abruzzo National Park. Fig. 1 refers to observations for the period 1994-1995. In the same period we did not record any change in the number of breeding pairs at three colonies in three different areas of the Abruzzo region.

Tab. 1 is based on observations from the present study and to data collected in the past (Allavena *et al.* 1986, Pellegrini and Di Giambattista 1993, Pellegrini *et al.* 1993), some of which were revised (Pellegrini unpubl. data).

The Golden Eagle (*Aquila chrysaetos*), the Lanner (*Falco biarmicus*) and the Peregrine (*Falco peregrinus*) were considered as being present if they nested in the same gorge as the Choughs or on the same isolated cliffs. We only considered other species if they nested within 100 metres of the Chough's nest or if they interacted with the Chough.

Results

Interactions with other species within the breeding areas

Tab. 1 shows the species that were observed to interact with the Choughs within the breeding areas. Interactions were most frequent with Jackdaws and Kestrels (*Falco tinnunculus*). There were Jackdaw nests within 100 metres of 29% of the Chough's nests (N=112). The minimum distance between nests of these species was 2 metres. In April four disputes for cavities were observed in two mixed colonies between pairs of Choughs and Jackdaws, one of which lasted for two days, and all terminated with the nesting of the Chough. We noted a case of kleptoparassitism of a chough that robbed branches from a nest of Jackäws and another case in which a Jackdaw robbed the lining material from a Chough's nest. In the laying period, of the 15 aggressive interactions casually observed between Jackdaws and Choughs of neighbouring nests (3-5 mt.) all terminated with the chasing away of the Jackdaws.

On the contrary the presence of the Raven (*Corvus corax*) was detrimental for the Chough, and in two different cases the Chough was replaced at two breeding cavities by pairs of Ravens at the beginning of the breeding season.

On the highest massifs Alpine Choughs (*Pyrrhocorax graculus*) were also present. They sometimes formed mixed flocks with the Choughs on the foraging grounds as it has been recorded in the Alps (Formica *et al.* 1995). Eight of thirty-six (22%) breeding cliffs with known colonies of Choughs sheltered pairs of the Alpine Chough, with a minimum distance between

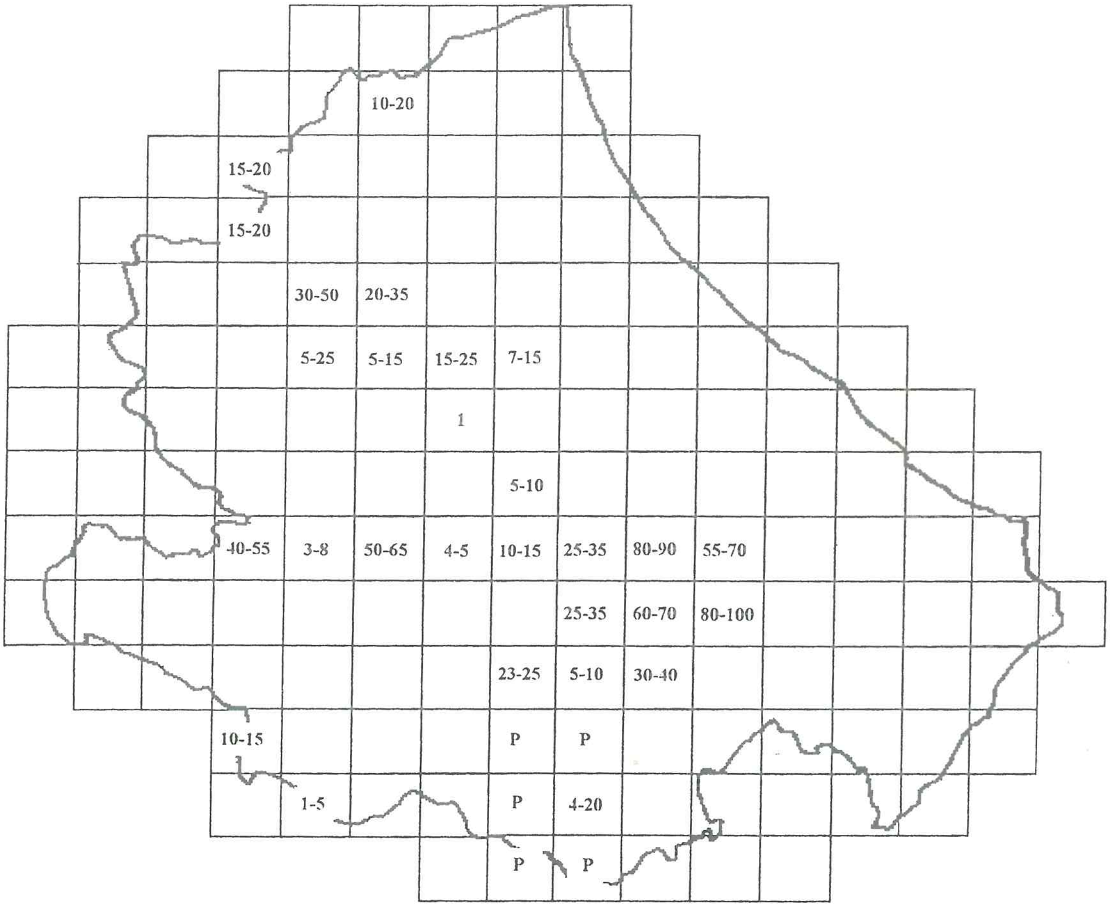

Fig. 1. Distribution and Status of the species in the Abruzzo region. Each square is 10000 hectars. An estimation of the minimum and maximum number of pairs is reported in each square. For that of the Abruzzo National Park only the presence is pointed out (P), except in one case. The species doesn't breed in squares without numbers.

Tab. 1. Species that interacted with the Chough within its breeding areas. The nearest-nest, the percentage of nest sites where the species were present nearby (see Methods for more explanations) and the types of interactions observed are reported.

Species	Nearest Nest (in metres)	%	Interaction observed
Falco tinnunculus	3	77 (N=115)	Mobbing by and on the Chough
Falco biarmicus	20	46 (N=105)	Predation attempts on and mobbing by the Chough
Falco peregrinus	200	45 (N=112)	Predation attempts on and mobbing by the Chough
Aquila chrysaetos	40	37 (N=111)	Predation on and mobbing by the Chough
Corvus corone cornix	-	-	Mobbing on the Chough
Delichon urbica	0.5	-	Mobbing on the Chough
Ptyoprogne rupestris	0.5	-	Mobbing on the Chough
Columba livia	20	-	.
Columba palumbus	-	-	Mobbing by the Chough
*Gyps fulvus**	-	-	Mobbing by the Chough
Martes foina	-	-	One pullus preyed on
Sciurus vulgaris	3	-	Mobbing and alarm with wing-flirting
Vulpes vulpes	-	-	Predation. Mobbing and alarm with wing-flirting
Homo sapiens	-	-	Alarm with wing-flirting.

*Ind. reintroduced

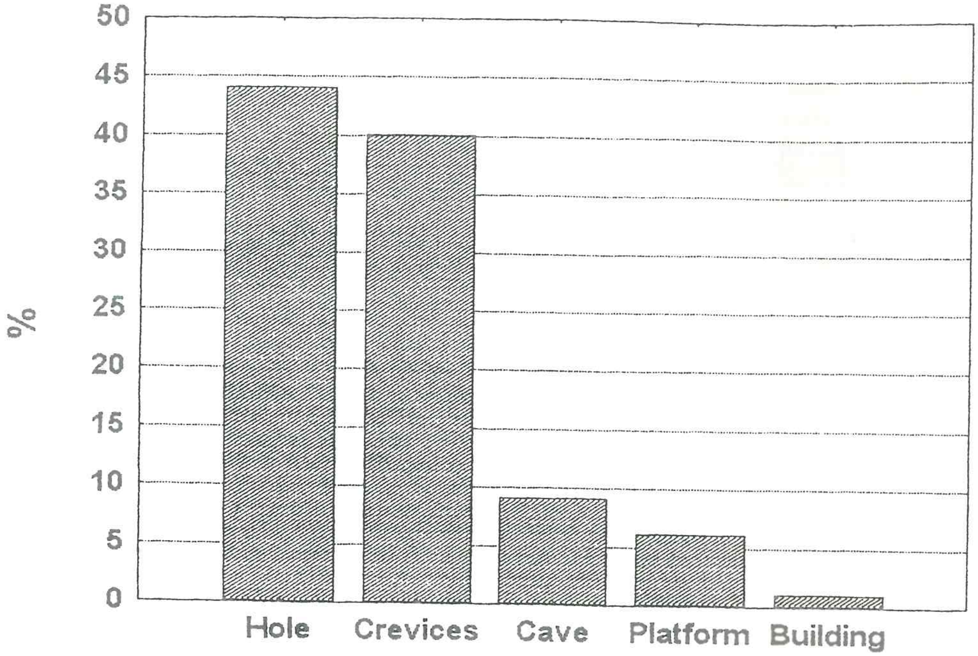

Fig. 2. Percentage of pairs for each type of nest-site (N=104).

nests of 50 metres. However, we did not observe any interaction in these breeding sites.

Breeding sites and productivity

Fig. 1 shows the distribution and an estimation of the pairs in the different areas of the region. There was a high concentration in the large massifs, with, in order of importance: the Majella-Morrone National Park (372-470 pairs), the Gran Sasso (86-171), the mountains of the Velino and the Sirente (97-133), the Laga Mountains (30-40), the Sagittario Gorge (23-25). There were also smaller groups of 10-20 pairs. We have no current estimate of the number of pairs in Abruzzo National Park, but 260-320 individuals were recorded in 1991 (Bernoni, *pers. comm.*). Flocks of 300 birds were observed on the Majella (September), on the Sirente (August) and in the northern part of the Gran Sasso (August).

The types of nesting sites used are shown in Fig. 2. The differences between the exposures of the nests shown in Fig. 3 are significant, with the North-east aspect clearly avoided (χ^2=34.41, DF=7, p<0,001).

The height of the cliffs with nests varied between 7 and 500 m., with the lowest nest being recorded at 5 mt. above the ground. The mean height of nests was 1282±440 SD a.s.l. (470-2450; N=112).The median and mode of the Nest Neighbour Distance (NND) was 20 m (2-11,000; N=103). In 84% of the cases the nests were within 50 m of each other. The feeding grounds were often 3-4 linear kilometers away from the nest, with a difference in height between nest and foraging sites of up to 800 mt. (600 to 1400 m).

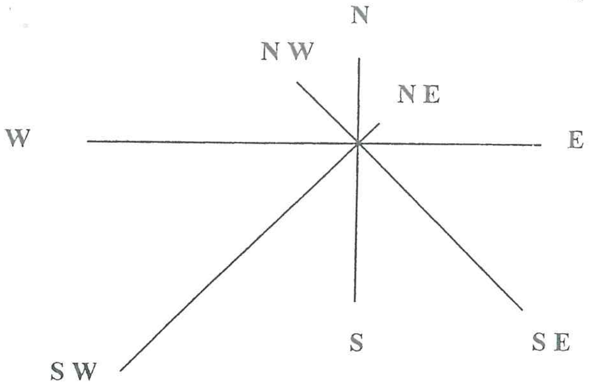

Fig. 3. Aspect of nest-sites. The lines are proportional to the number of nests. The North-east exposure has two nests.

In 1994 fledging dates were strictly related to altitude (Fig. 4). The range of fledging dates regarding the three years varied between 05 of June and 15 of July. Fig. 5 shows the actvity at the nests of the Sagittario Gorge colony.

Tab. 2 reports data per years about the productivity of the 55 breeding attempts observed. Difference in medians in productivity in 1994 and 1995 is not significant (Mann-Whitney U, z adj.=-1.49, DF=1, p=0.14).

The average of 2.40±1,26 DS young fledged per nest

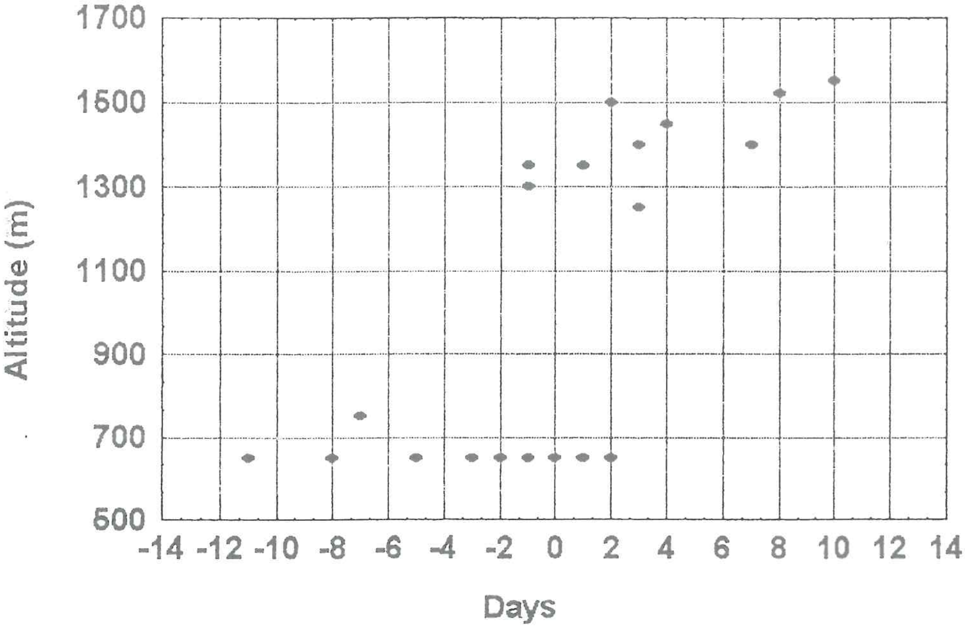

Fig. 4. Relationship between altitude and the date of the first young fledged per nest in 1994 (expressed as deviations from the median fledging date). Median 19 of June (Spearman R=0.75, T=4.76, P<0.001, N=20)

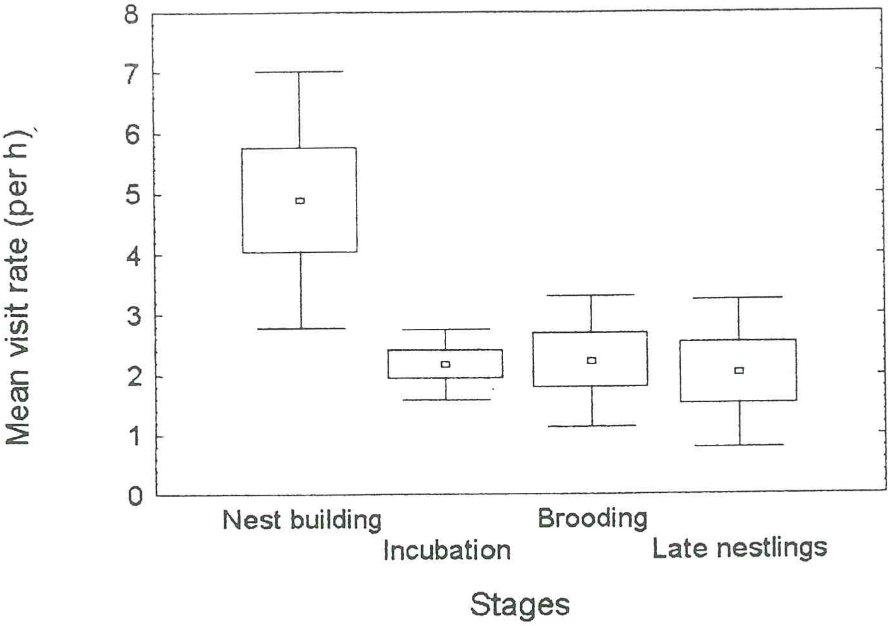

Fig. 5. Activity at the nests in the four stages of the breeding period. For each stage we considered the mean of the two days of observation for each of the six nests. Differences in the means of visits per h are significant (one-way ANOVA, $F_{3,20}=4.26$, p=0.018, after a square root transformation of the data). Days of observation: 13, 15 April (nest building), 05,06 May (incubation), 19,21 May (brooding) and 13,14 June (late nestlings). The height of each rectangle shows standard error; vertical lines show standard deviation; points show means.

Tab. 2. Productivity of young in the three years of the present study.

Year	N. nests	Mean±DS
1993	5	3±1
1994	23	2.6±1.03
1995	27	2.2±1.42
three years	55	2.4±1.25

rises to 2,68±1.04 DS if 5 breeding attempts where failure was verified (1 in 1994, due to interference by man, and 4 in 1995) are not considered.

A comparison between data relative to Ireland (2.85±1.04DS young per pair) and ours is possible because those reported by Bullock *et al.* (1983) also concern only successful pairs. The slight difference between these data is not significant (*z*=1,077, NS).

In 1995 in the colony of the Sagittario Gorge we verified the reproduction of a female ringed as a pullus in 1993 in the same place. Therefore it reproduced in its second year of life.

No observations of nest helpers (Jennings 1984) were made.

Very often breeding cliffs or nest sites were used year round as roosting sites by breeders and non-breeders (De Sanctis 1995).

We recorded four causes of mortality of fledged young: collision with cars in a tunnel near the nest (2 cases), necrosis due to the hairs of the nest lining becoming wound around a claw (2 cases), predation by a stone marten in the nest on a cliff (1 pullus), and impossibility to fly due to some problems to the wings (2).

Discussion

The population of the Chough in Abruzzo represents the stronghold of the species in Italy (Meschini and Frugis 1993, Orlando 1992, Sorci *et al.* 1971, Rolando *comm. pers.*) In some areas (De Sanctis 1995, Pellegrini *et al.* 1995, this study) density approached those reported for Spain (Blanco *et al.* 1993) and the number of pairs, 633-899 without those of the Abruzzo National Park, was fairly similar to that of the entire Irish population (Berrow *et al.* 1993). The importance of the Majella-Morrone National Park (84,000 hectars of extension) was highlighted (see Pellegrini *et al.* 1995), supporting half of the breeding pairs, more than 200 individuals/10.000 hectars and flocks of 300 individuals. Similar density was recorded in the Hoya de Guadix in Spain (Soler 1989). In the Velino-Sirente Regional Park there was the biggest colony of the Abruzzo region, with at least 40 pairs along 2 Km. of cliffs, with a density similar to that reported for the area studied by Blanco *et al.* (1991) in Spain.

The percentage of non-breeding birds resulted high (between 35% and 60%) as in Portugal (Farinha 1991) and in Ireland (Berrow *et al.* 1993). Considering our data we estimate the presence of 2,000 individuals at least in our region (without those of the Abruzzo National Park).

The fact that the species avoided north-eastern exposure was probably related to the lesser protection against the prevailing cold winds of the region. Breeding in man-made structures, as recorded in Spain and Scotland (Blanco *et al.* 1993, Monaghan *et al.* 1989), is negligible in this study, with only one nest in 115 being made in a building. Probably the presence of numerous rocky cliffs and the scarcity of ancient and isolated buildings did not encourage the use of man-made structures for nesting sites (Blanco *et al.* 1997). Forms of disturbance did not seem to affect particularly the choice of the nesting site (not even the explosion of some mines in World War II, Di Giambattista *pers. comm.*). At the Sagittario Gorge colony there were some nests about 10 m above a road with fairly heavy traffic. On the contrary, tourism at the feeding grounds could affect the foraging efficiency of Choughs (Owen 1989a, pers. obs.).

In Abruzzo the Chough is mostly a colonial breeder (sensu Mϕeller 1987). Colonies were reported in Sicily, in the Maritime Alps and in Spain (Mingozzi *et al.* 1988, Sorci *et al.* 1971, Zuniga 1989) whereas in other areas of Europe, such as the British Isles, the Norhern Alps (Val D'Aosta), and Portugal (Bullock *et al.* 1983, Farinha 1991, McCracken *et al.* 1992, Rolando *pers. comm.*) the Chough was found to be a territorial bird.

The activity at the nests of colonies resulted higthly synchronized, with the pairs (or the males) flying together from the feeding grounds in more than 50% of the cases (pers. obs in five colonies). Moreover we observed three communal defences of the nests at the colony of the Sagittario Gorge against: a stone marten, a fox (*Vulpes vulpes*) and a squirrel (*Sciurus vulgaris*). The latter could prey on the eggs in the nests. In addition, communal defence against the Golden Eagle on the breeding grounds was commonly observed (13 in 1995 for one site). These observations might suggest some benefits for the individuals living in colonies. Coloniality might, however, have some costs, with a greater exposure to parasites and an increase in unfavourable intraspecific interactions (Hoogland 1979, Mϕeller 1987). In fact, we noted some cases of aggressive interactions between members of two pairs with nests very close to each other (3 metres) and three cases of kleptoparasitism regarding material of the nest. None the less in other cases with pairs very close to each other we did not observe such negative interactions.

Regarding productivity, we·have probably underestimated the pairs that failed to breed because of the possible inclusion of pairs making first (failed) breeding attempt (Bullock *et al.* 1983).

We recorded the successfull reproduction of a female in her second year of life, as reported by Bullock *et al.* (1983).

The activity at the nests reached its maximum at the nest-building stage, when we recorded a number of visits at the nest site spaced only one minute from one another. However at the same stage we noted an absence from the nest site of 155 minutes.

Within a colony at a given height, reproduction was usually synchronized, with all the fledgings of the colony abandoning all the nests within 10-15 days. The fledging date was strongly related to altitude, at least for 1994.

Regarding the hypothetical competition between the Chough and the Jackdaw (Farinha 1991), while Soler and Soler (1993) demonstrated the lack of feeding competition, our observations indicated competition within the nesting sites. However these antagonistic interactions resulted in the dominance of the Chough and the sites normally used by the Jackdaw resulted less deep than those used by the Chough (Storero *et al.* 1988, pers. obs.) On the contrary, the Raven could be a very unfavourable competitor in the displacement of the Chough from its breeding sites, eating pulli (Zùñiga 1989) and fledged young (Bignal *pers. comm.*).

The strong reactions to the appearance of a fox near the colony were due to the fact that this species could be the most important predator of the adult Chough (*pers. obs.*, Zùñiga 1989) along with the Golden Eagle (two captures were observed, but in one case an individual taken and carried to the nest by an adult eagle escaped when he was left in the nest!). The Peregrine, sometimes mobbed by the Chough, did not clearly affect the choice of the breeding areas of the Chough. Moreover we observed 21 cases of a Peregrine attacking Choughs but the latter was never killed.

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Riassunto - La biologia riproduttiva del Gracchio corallino è poco conosciuta in Italia. Alcune ricerche in Abruzzo hanno confermato l'importanza di quest'area per la specie. In questo lavoro vengono stimate 633-899 coppie di riproduttori, distribuite sui massicci più importanti ed è quindi stimata la presenza di almeno 2,000 individui. Dal 1993 al 1995 sono stati seguiti 55 tentativi di riproduzione, con una media di 2.40±1.26SD giovani involati per coppia. La maggior parte delle coppie è risultata nidificare in colonia. Il periodo riproduttivo inizia alla fine di Marzo e i giovano si involano fino all'inizio di Luglio. Nel 1994 il momento dell'involo è risultato fortemente correlato con la quota, con un ritardo nelle coppie a quote maggiori. L'attività presso i siti riproduttivi è massima durante la costruzione del nido. Vengono riportate alcune cause di mortalità dei giovani e le interazioni con altre specie presso i siti di nidificazione. È confermata la competizione con la Taccola (*Corvus monedula*) per le cavità di nidificazione, risultando in una dominanza del Gracchio corallino.

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Nesting biology of Whiskered Tern *Chlidonias hybridus* in Croatia

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Abstract - The nesting biology of the Whiskered Tern, *Chlidonias hybridus*, was investigated at the Končanica Fish Farm in northern Croatia in 1989 and 1993. Data on population size, breeding, nest shape, composition, size and location in relation to vegetation are presented. Studies were made of egg and clutch size, incubation and hatching.

Introduction

The Whiskered Tern, *Chlidonias hybridus*, has a discontinuous range in Europe (Voous 1960). It is a colonially nesting species which occurs only occasionally in small numbers in mainland Croatia. In Europe the breeding biology of this species has not been fully investigated. No data on breeding success, territory size and nesting density in a colony have been presented for the area of the western Palearctic (Cramp 1985). Studies of the Whiskered Tern in Croatia have so far dealt mainly with locality and size of the nesting population (Rucner 1962, Rucner and Rucner 1972, Mees 1979, Delić 1988, Schneider 1988). This paper examines hatching success and nest density of Whiskered Terns in Croatia, as well as nest shape and size, egg and clutch size, and vegetation used for nests by the birds.

Study area, material and methods

The research was carried out at a 21ha pond (No. 5) in the Končanica Fish Farm in central Croatia (45° 38^{I}, 45° 44^{I} N; - 17° 03^{I}, 17° 11^{I} E) from May to August in 1989 and in 1993. The Končanica Fish Farm consists of 24 ponds with a total area of 1400 ha stretching along the left bank of the River Ilova. During these studies the entire area of the Farm was surveyed to determine the nesting sites of the Whiskered Tern.

A part of pond No. 5 runs along the riverbank and is overgrown with dense vegetation (*Phragmites communis, Typha sp., Carex sp.,* and *Schoenoploectus lacustris)* which is cut once a year. The cut plants are left on the water where they float on the surface. The emergent floating flora consists of *Trapa natans, Polygonum amphibium, Potamogeton natans, Nuphar luteum, Nymphoides peltata* and *Lemna sp*. The submersed flora consists of *Myriophyllum spicatum, Potamogeton pectinatus, P. crispus, Ceratophyllum demersum* and *Najas sp*. Fishpond No. 5 is the only one in which *Polygonum amphibium* forms vegetation islets of relatively large area in the middle of the pond. In the other ponds it occurs only along the edge or in small central areas.

Whiskered Tern nest composition and structure were examined in 1989, while in 1993 clutch size, incubation and hatching were investigated. Measurements were made of all the 105 nests found, and of a sample of 151 eggs. Egg size (breadth and lenght) was measured with callipers, while nest dimensions and water depth were measured with a tape measure. Incubation was observed in a sample of 5 nests, and hatching intervals in a sample of 15 nests. The eggs (with markers) and the nests (with numbers on plastic tape) were marked for this purpose. Hatching success was investigated in 1993 by means of the ratio between the number of eggs laid and the number of them that hatched; clutches were checked every day. Nest density was measured as the number of pairs (nests) per 100 m^2 within each subcolony in 1989 and 1993.

Adult sex differentiation was assesed by the male and female morphological descriptions presented by Spina (1982).

During 1990 and 1991 nesting was interrupted and then completely abandoned because of water being drained from the fish pond. In 1992 there were no nesting attempts, even though there was both water and vegetation in the pond.

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Results

Breeding and Nest Location

The Whiskered Tern nested only on pond No. 5 of the Končanica Fish Farm, and in 1989 and 1993 this colony was the only one. The nests were built exclusively on islets of floating *Polygonum amphibium*. In 1989 there were three islets supporting 3 subcolonies. In 1993 five islets in the middle of the pond supported 6 subcolunies. The islets were 3-15 m apart. The water depth at the colony site was 49-57 cm on 19th June 1993.

Nests

The Whiskered Tern nest was usually cone-shaped, considering of a basal platform and a central cone in which the cup was located. The material for the platform consisted of broken stalks of *Phragmites communis, Typha sp.,* and *Polygonum amphibium.* Platform diameters ranged from 37 to 55 cm with an average of 42.4 ± 2.27 cm. Eggs were laid in the nest cup, made of *Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton sp., Schoenoploectus lacustris, Typha sp., Phragmites communis* and *Polygonum amphibium.* The nest cup diameters ranged from 7 to 15 cm with an average of 9.2 ± 1.45 cm. Only 2 of the 105 nests did not have a cone, being completely horizontal. Cone height was 1 cm in 48.6% of the nests, and ranged from 0 to 9 cm, the average being 2.2 ± 1.77 cm. The inside of the cup was of a finer material and consisted mainly of *Myriophyllum spicatum,* with smaller quantities of *Ceratophyllum demersum* and *Potamogeton sp.,* although several were without a finer lining. The nests were tied to the floating vegetation by means of long stalks of *Schoenoploectus lacustris.*

Population

In 1989 there were 69 active nests. Nest building started on 18th May, and on 9th June there were 31 nesting pairs distributed among three subcolonies. Nest density was on average 1.43, 1.50 and 1.66 pairs/100 m2 (Table 1). The nesting of these 31 pairs during June 1989 ended with the successful fledging of an unknown number of young at the end of June. On 25th July 1989, 38 new nests with eggs were observed in the same area, but the fate of these eggs was not investigated.
In June 1993 there were 105 pairs occupying nests on five islets in the middle of the pond and on one islet of 750 m 2 at the edge of the pond. Nest density ranged from 1.84 to 11.66 pairs/ 100 m 2 (Table 2).

Eggs, Incubation and Hatching

In 1993, 96 pairs laid a total of 253 eggs (Table 3). Excluding nine nests where pairs did not lay eggs, the mean clutch size was 2.64 ± 0.77 eggs per nest. Of a total of 253 eggs, 22 disappeared, probably due to predators, and 9 eggs were addled and did not hatch. This resulted in a hatching rate of 87.7%. Eggs were laid at regular intervals of about 24 h. The background color of the eggs was olive green with brown, yellowish or grey shading and with black/brown spotting. The egg size averaged 38.4 ± 1.83 X 27.8 ± 0.99 mm. Incubation was shared by males and females and, in almost all pairs observed, began before the last egg was laid. In three out of five nests, the chicks hatched after 20 days of incubation, in one nest after 19 days, and in one after 18 days. The young of a brood hatched almost synchronously: hatching occurred at intervals

Table 1. Subcolony area, number of pairs in a subcolony and nest density in Whiskered Tern within subcolonies in 1989.

Size of areas of subcolonies (m^2)	Number of pairs in June	Nest density (pairs/100 m^2)
300	5	1.66
350	5	1.43
1.400	21	1.50
Total: 2.050	31	1.51

Table 2. Subcolony size, number of pairs in a subcolony and nest density in Whiskered Tern within subcolonies in 1993.

Breeding areas of subcolonies (m^2)	Number of pairs	Nest density (pairs/100 m^2)
10	1	10.00
60	7	11.66
90	3	3.33
120	5	4.16
750	41	5.46
2.600	48	1.84
Total: 3.630	105	2.9

Table 3 - Distribution of the number of eggs per nest, frequency of the number of nests (n) and percentage (%) of nests of the Whiskered Tern in 1993.

Clutch size	Nests	
	n	%
0	9	8.6
1	11	10.5
2	18	17.1
3	63	60.0
4	3	2.9
5	1	0.9
Total:	105	100.0

of several hours but within an interval of 20 hours in three nests out of a total of 15.

The young

The body color of young Whiskered Terns is camouflaged (Plate 12 in: Cramp, 1985), down being replaced by feathers during the first 20 days of life. The young were semi-nidifugous, leaving the nest between 3 and 8 days. They were fed by both parents.

Discussion

At the Končanica Fish Farm in 1989 and 1993, the Whiskered Tern nested exclusively on floating *Polygonum amphibium* vegetation. However, on the open waters in Val Campotto in the northern part of the Appennines (Italy) in 1980, the species nested mainly on *Nymphaea alba* (Spina 1982, Spina 1990).

While the platforms at Končanica were built of stems of three plant species (*Phragmites communis, Typha sp.*, and *Polygonum amphibium*), in Val Campotto they were made from stalks of two species, i. e. *Phragmites communis* and *Nymphaea alba* (Spina 1982); one species (*Phragmites communis*) is common to both study areas. The diameter of the nest platforms of the Whiskered Tern at the Končanica Fish Farm was about 9 cm smaller, on average, than those in Val Campotto (Spina 1982) (Table 4). This could be explained by habitat-linked differences in basic vegetation where the nests are located. Nests in Croatia were situated exclusively on *Polygonum amphibium* islands, while in Italy they were on *Nymphaea alba*. The difference in the cup diameter between these two populations was not statistically significant.

In areas where *Nymphaea alba* grows in Croatia, the Whiskered Tern has been observed nesting on this plant in open water, e.g. in the marshy area of Kopački rit in the period 1957-58 (Rucner 1962). Elsewhere in Croatia it was observed nesting on floating islands of cut vegetation including *Salix sp.* At the Pakrac Fish Farm in 1989 the terns were in a mixed colony with the Black-headed Gull *Larus ridibundus* (Mužinić, unpublished data). In the period 1957-58 they nested on mats of *Phragmites communis* (Rucner 1962).

The eggs were laid at one-day intervals, which agrees with the findings of Spina (1990). According to Cramp (1985), nests with 4 and 5 eggs originate from two different females laying their eggs in the same nest; the three nests with 4 eggs each and one nest with 5 eggs recorded at Končanica Fish Farm (Table 3) can be explained in this way. The mean clutch size was similar to that recorded in Italy by Spina (1982) in 1980 (2.57 ± 0.80). The lower clutch size in 1980 and 1981 (1.52 ± 1.32 eggs per nest) recorded by Spina (1982) could be the results of predation or annual variation in clutch size.

The egg size in the Croatian population shows, on average, a smaller minimum and maximum diameters than the eggs measured by Spina (1982) in 1980, the difference being statistically significant ($P < 0.0001$) (Table 5). Thus, these two breeding populations with the same clutch size appear to have a significant difference in egg size. This could be explained by

Table 4. Diameter (Ø) of nest platform and trough in Whiskered Tern populations in Croatia and Italy according to Mužinić & Delić (this paper) and Spina (1982).

	Mužinić & Delić				Spina				
Ø	N	X	±	sd	N	X	±	sd	t - test
Platform	105	42.4	±	2.27	38	51.7	±	14.0	t = 6.582 P < 0.0001
Trough	105	9.2	±	1.45	38	11.9	±	2.9	t = 0.950 N.S

Table 5. Egg size in Whiskered Tern from Croatia and Italy according to Mužinić & Delić (this paper) and Spina (1982).

	Mužinić & Delić					Spina				
Eggs	N	Min/Max	X	±	sd	N	X	±	sd	t - test
Breadth	151	25.0/30.1	27.8	±	0.99	100	28.41	±	0.77	t = 5.120 P < 0.0001
Length	151	31.3/44.1	38.4	±	1.83	100	39.48	±	1.54	t = 4.688 P < 0.0001

different conditions influencing the food availability during egg-laying, as noted in the Common Tern, *Sterna hirundo* (Becker *et al.* 1985), and the Arctic Tern, *Sterna paradisea* (Monaghan *et al.* 1992). An additional reason could be an age difference of laying females, as found in the Red-billed Gull, *Larus novaehollandiae* (Mills 1979), and in the Shag, *Phalacrocorax aristotelis* (Coulson *et al.* 1969). The egg size of the populations at the Končanica Fish Farm was also slightly smaller than that reported by Hartert (1912-1921) (39.23 x 28.45 mm) who did not specify the population of origin.

After successful fledging at the Končanica Fish Farm in June 1989, there were 38 pairs nesting in the same breeding area (total surface area 2050 m^2) in July of the same year. This was seven pairs more than in June, which would indicate that there was no nesting delay in June by a part of the population due to lack of space. Observations in the surrounding area in which Whiskered Tern may choose a nesting place did not reveal any flying birds, i.e. individuals waiting for free nesting places. It is generally accepted that the Whiskered Tern has only one brood per year and that it nests again only if the first brood is lost (Cramp 1985). Hence the question remains open as to whether this nesting in July was a delayed first nesting attempt, a renesting of birds which had failed earlier, or a second nesting of the same population. A similar dilemma is reported by Spina (1982) in the case of 8 pairs of Whiskered Tern at Val Campotto nesting on 13th August 1981.

Water was let out of pond No. 5 in June 1990 for fish harvesting, causing an interruption of nesting that had already begun. Glutz von Blotzheim & Bauer (1982) also reported that a sudden drop in the water level led to the total loss of broods. The lowest water level at which nesting occurred at the Končanica Fish Farm was recorded in 1993, when it ranged from only 0.49 to 9.57 m. At the Pakrac Fish Farm (Croatia) in 1989, the water level was 1.20 m (Mužinić, unpublished data), while in Val Campotto it was 1.0 m (Spina 1982).

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Relationship between Robins (*Erithacus r. rubecula* L.) morphology and habitat occupancy

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Abstract - A relationship between Robins' morphological differences and the individual habitat occupancy has been found on a small island off the coast of southern Italy, during the winter. Characteristic habitats were: low scrub, high scrub, olive-orchard and *Quercus* wood.
The study has shown different Robins abundance among habitats. Multiple discriminant analysis has shown that birds occurring in different habitats differed from one another morphologically, both in body size indices (wing, tail, and tarsus length) and in bill size (bill-length and volumes).

Introduction

It is a common knowledge that morphology is correlated to bird ecology (James 1982, Tiainen 1982). Several studies have focused on the relationship between birds morphology and habitat selection (Baker 1979, Trevis and Ricklefs 1983), foraging methods, and feeding habits (Leisler and Thaler 1982, Gosler 1987, Jordano 1987). Thus, a morphological approach has sometimes been used to test interspecific competition (Travis and Ricklefs 1983, Moulton 1985).

Interspecific eco-ethological differences may also be related to morphological differences among individual birds (Hamilton 1961, James 1982). For example, body size changes according to the differences in latitude, elevation and climate (Mayr 1942, Snow 1954, Moreau 1960, Hamilton 1958, James 1970). Furthermore, a close relationship between morphology and intraspecific habitat selection has also been described. For example, Van Balen (1967) and Ulfstrand *et al.* (1981) found out that birds of a *Parus major* population select their habitat according to their body size. Similarly, Miller (1931) and Pitelka (1951) have shown that wing length of *Lanius* and *Aphelocoma* species is correlated to vegetation density.

In the Mediterranean area a large number of passerines coexists in small areas such as islands during the winter, showing so habitat segregation (de Filippo 1984, de Filippo and Fraissinet 1984). The Robin (*Erithacus r. rubecula)* is particularly common among them (Harrison 1982, Scebba and Oliveri del Castillo 1985) and it presents a positive habitat selection for olive orchards (Milone *et al.* 1981).

The present study investigates if individual preferences for specific types of Mediterranean vegetation in wintering Robins are related to intraspecific morphological differences.

Methods

Study area

Vivara Island (32 ha) is situated off the coast of southern Italy (40° 44' N, 13° 59' E) and it is an important wintering area for passerines. It has a typical Mediterranean vegetation (Caputo 1981) which consists of four different types:

LS - low scrub (up to 1.5 m), consisting chiefly of *Myrtus communis*, *Cistus* spp., *Pistacia lentiscus*, *Rubus ulmifolius* and *Euphorbia dendroides*;

HS - high scrub (over 1.5 m) consisting in *Arbutus unedo* and *Erica arborea*;

OL - uncultivated olive-orchard, presenting a wide variety of other species of plants also present in the high scrub;

WD - *Quercus pubescens* wood, presenting a low numbers of other species of plants (e.g. *Smilax aspera*);

Data collection

We used collected data on birds communities on Vivara Island (South Italy). Three days a month we set up mistnets in 22 different sites distributed among the four

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types of vegetation according to their extension. Since the mist-net efficiency may vary according to the habitat, we took care of using mist-nets standardised on the basis of the following methods: 1) we set up the nets in sites where visibility was as far as possible the same; 2) in the open habitats (with scarce vegetation) , the nets were placed so that they weren't exposed to wind; 3) since birds which made use of different types of vegetation could have different activity patterns during the day (Karr 1981), we spread the nets all day long (both in the sunshine and in the darkness); 4) the nets were only 3 m high because Robins mostly feed on under a 3 m high scrub (Milone *et al.* 1981, Boe and Fraticelli 1988). As a matter of fact, we expected no differences between the capture rates in the wood and in the olive-orchard and the capture rates in scrub habitats (over 3 m high).

Captured Robins were ringed, aged, measured (see below) and released. For each bird the following measurements were taken: (see Svensson 1984 for methods) wing-length (maximum chord), tail-length and tarsus-length. In many birds, the above mentioned measurements were taken because they are good indices of body size (e.g. in Willow warbler: Fonstad and Hogstad 1981).

In particular, the wing length is correlated to the length of feathers and bones (Calhoun 1947) and fat-free weight (Connell *et al.* 1960).

The bill-length, width and depth at feathering were also measured to 0.1 mm with a calliper. We used these measurements to calculate bill-volumes, considering bills as pyramids with a triangular base.

The bill-length and the volume were considered as indices of food habits (Betts 1955).

Although the bill-length is usually measured at skull (Svensson 1984), in this study we thought right to use length at feathering because the measure at feathering is a better method to calculate bill volumes (see bill length in Svensson 1984, pag. 19).

Each bird was aged by the inside colour of its upper mandible, the central rectrices shape and the wing spots (Svensson 1984).

Data analysis

For each habitat, the capture rate has been expressed as birds first-time caught /100 m^2 of nets /10 hours.

Observed vs. random frequencies of capture and recapture rate was checked by χ^2 Brand-Snedecor test (Scossiroli and Palenzona 1979).

The habitat breadth was measured by $AH=\sum \min(p_i,q_i)$ (Smith 1982), where pi is the occurrence of birds in each habitat "i" and q_i is the relative frequency (area) of each habitat on the island. The distance between observed and expected AHs in case of random distribution among habitats (AH=1) was statistically checked by the variable $z=(AH-1)/\sqrt{Var(AH)}$, where Var(AH) was calculated by Smith (1982).

Since the measurements were not normally distributed, the data were passed into normality taking their log10 (Sokal and Rholf 1981).

We checked the differences in the average $\log_{10}$ values through the t-test for not-matched groups.

Multiple discriminant analysis (Davies 1971) was used to evaluate how the birds measurements varied in the different habitats. The equality between these 4 groups and the significance of the eigenvalues was checked according to Bartlett's test (Davies 1971).

Results

The 203 Robins captured during the winter on the Vivara Island (Fig. 1) are not equally distributed among the four habitats (AH=0.809; statistical differences vs. random distribution AH=1.0: $P<0.01$). Juvenile (first-winter) and adult birds show the same distribution in the different types of vegetation ($\chi^2=2.92$, d.f. = 2, $P>0.20$).

The study shows different retrap rates from one habitat to another, with lower values in the low and high scrub ($\chi^2=16.7$, d.f. = 2, $P<0.001$).

There were significant morphological differences in birds for each different type of vegetation (Tab. I-III). As concern the body size variables, the eigenvalue discriminates 85.4 % of the individuals. Birds trapped in olive-orchards, have tails and *tarsi* significantly shorter than birds trapped in other type of vegetation (tail: $P<0.05$ vs. wood and low scrub; tarsus: $P<0.01$ vs. low scrub, $P<0.001$ *vs.* high scrub and wood; t-test).

As concern the bill variables the eigenvalue discriminates 99.2 % of the individuals. The bill volume is largest in birds living in the high scrub and olive-orchard (high scrub: $P<0.05$ *vs.* low scrub; olive-orchard: $P<0.001$ *vs.* low scrub, $P<0.01$ *vs.* wood; t-test).

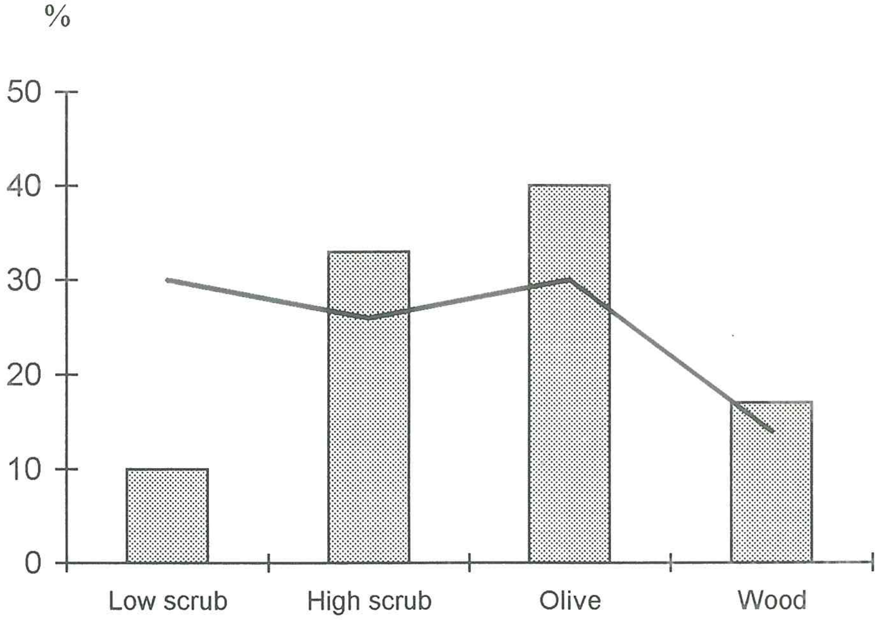
Discussion

Robins select the olive orchard and the high scrub according to food abundance. In fact, during the winter they feed on a wide variety of berries as *Arburtus unedo*, *Myrtus communis*, *Olea oleaster*, *Phillyrea* spp. and *Pistacia lentiscus* (Herrera 1981, de Filippo *et al.* 1985), widespread in this vegetation. The wind exposure of this habitat causes poor selection in the low scrub, since the wind increases birds heat loss (Goldstein 1983).

It is, of course, possible that a part of the variability was due to a better capture methods efficiency in each different habitat, in spite of the great care taken in avoiding any discrepancy in efficiency.

The birds occurring in the olive orchard and high scrub are the smallest ones, but they show a larger bill volume.

It is possible to explain the morphological differences between the birds in the habitats by the presence of different populations on the island. In fact, Robins' winter populations arrive on the Vivara Island at different times from September to April (Lovei *et al.* 1984). Some of them are more erratic than others and exhibit a strong territorial behaviour (de Filippo *et al.* 1991) and a site fidelity (Lovei and Scebba 1986). Smaller birds (local migrants or southern populations) might arrive earlier, and take up territories chiefly in the olive-orchard. Migrating birds from farther north-



	Low scrub	High scrub	Olive	Wood
n:	8	106	68	21
R:	38	27	57	57

Fig. 1. Occurrence of birds trapped (columns) in the different vegetation types. Line shows the occurrence of each type of vegetation on the island. n: sample size. R: retrap rate (%).

Tab. I. Robin measurements (mean ± S.E. in mm, except bill volumes in mm^3).

	WING	TAIL	TARSUS	BILL LENGTH	BILL VOLUME	n
Low scrub	70.2 ±0.5	57.1 ±2.8	24.5 ±1.4	11.0 ±2.0	56.9 ±17.6	8
High scrub	71.3 ±2.2	54.8 ±4.3	24.3 ±2.5	11.7 ±2.1	94.4 ±46.9	106
Olive orchard	70.8 ±2.1	53.7 ±4.6	22.6 ±1.8	11.8 ±1.8	104.5 ±43.6	68
Wood	71.3 ±2.4	56.1 ±4.2	24.6 ±2.1	11.5 ±1.6	76.7 ±27.7	21
TOTAL	71.1 ±2.2	54.7 ±4.4	23.8 ±2.4	11.7 ±2.0	94.5 ±44.5	

Tab. II. Multiple discriminant analysis on Log_{10} transformed measurements indices of body size.

Equality of group means	$X^2 = 36.7$, d.f. = 9, $P<0.001$
Eigenvalue	0.170 ($X^2 = 31.06$, d.f. = 5, $P<0.001$)
Percentage discrimination	85.4 %
Eigenvectors	
Wing	0.644
Tail	0.112
Tarsus	0.757

Tab. III. Multiple discriminant analysis on Log_{10} transformed measurements indices of bill size.

Equality of group means	$X^2 = 26.6$, d.f. = 6, $P<0.001$
Eigenvalue	0.142 ($X^2 = 26.4$, d.f.= 4, $P<0.001$)
Percentage discrimination	99.2 %
Eigenvectors	
Bill length	0.855
Bill volumes	-0.519

ern populations have to pass through other habitats because of the territorial behaviour of the first-arrived birds. Furthermore, the high retrap rate (Fig. 1) in the olive-orchards suggests that these birds (smaller and probably belonging to the southern populations) are less erratic and more closely linked up to the territory. The preference for the olive orchards, might be due to a different body size fitness to the different habitats and related to the preference for the exploitation of berries as food (de Filippo *et al.* 1991).

Interspecific studies on the genus *Sylvia* (Jordano 1987) showed that morphology sets limits to the degree of frugivory. In these species body measurements were correlated to a frugivory index and a less robust bill-shape increased the variability of the fruit they ate. Also intraspecific studies on *Parus major* (Gosler 1987) have found that bill size variability is correlated to diet differences.

Robins' intraspecific variability on the Vivara island is large enough to suggest that in this populations too, morphology might affect the costs-benefits balance associated with the frugivorous diet (Jordano 1981, de Filippo *et al.* 1985). In fact, the variation coefficients were 14.9 % and 8.0 % considering tail, 12.8 % and 10.1 % considering tarsus, 18.3 % and 17.1% considering the bill-length respectively in *Sylvia* (Donana: Jordano 1987) and in the Robin (Vivara: this study). Furthermore, the variation coefficient of *Parus major* bill size (Gosler 1987 study: 3.3 %) is less than the one measured in the Robins (this study: 5.2 %).

A relationship between the Robins' morphology and the food size was described by Herrera (1978), considering the invertebrate prey. Since birds use the adaptive patterns developed for insect capture and handled to forage on berries (Herrera 1984), a large bill volume might also permit to feed on berries of a wider size. Thus, according to this hypothesis, birds with larger bill volumes might exploit the wide variety of berries occurring in the uncultivated olive-orchard.

Although most suggestions concerning the relationships between body size and habitat are related to the bill size, we can also explain the different tarsus or the tail length on the basis of supposition on the feeding behaviour and the berries selection; in fact, many morphological patterns other than the bill size are related to the food search and ingestion (James 1982, Leisler and Thaler 1982).

However, the largest size of birds in the low scrub might be related to the higher resistance of large body size of robins against the heat loss consequent the wind exposure.

Further experimental research are request in order to select which of these hypothesis can be more reliable in determining the observed relation between morphology and habitat selection.

However, we consider each hypothesis reliable and our results might be considered as the consequence of several environmental forces acting on different populations in various ways.

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Autumn migration of Accipitriformes through Italy en route to Africa

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Abstract - A survey on the autumn migration of Accipitriformes along the Calabrian Apennines (southern Italy) was carried out from 11 August to 10 October 1996. A total of 2385 raptors were counted, mostly Honey Buzzards *Pernis apivorus*, Marsh Harriers *Circus aeruginosus* and Black Kites *Milvus migrans*. Both adult and juvenile Black Kites and Marsh Harriers migrated in the same period, concentrating during the third 10 days of August and the first three weeks of September respectively. These species use different routes to cross the central Mediterranean; hundreds of Marsh Harriers concentrate over Malta while Black Kites cross the sea between Sicily and Tunisia. In the case of the Honey Buzzard, a partial overlap of migration periods of young and adults was observed during the first 10 days of September. Our observations suggest that at least part of Short-toed Eagles *Circaetus gallicus* breeding in central Italy do not cross the central Mediterranean. They probably cross the Mediterranean Sea at the Straits of Gibraltar, passing over the Ligurian Apennines (northwest Italy). This hypothesis suggests information transmission between adults (expert individuals) and young (inexpert individuals).

Introduction

During autumn migration across the central Mediterranean, a notable concentration of raptors, especially Accipitriformes, occurs on the Calabrian Apennines (southern Italy) where the distance between the Tyrrhenian and Jonian coasts is narrowest (approximately 30 km, Fig.1) (Agostini and Logozzo 1995a). Since 1992, at the Calabrian Apennines, observations have been made mostly on the Honey Buzzard *Pernis apivorus* (Agostini and Logozzo 1995b, c, Agostini *et al.* 1997). Adult Honey Buzzards were observed from the end of August to the beginning of September, and cross the central Mediterranean at its narrowest point, between Sicily and Tunisia, concentrating over the island of Marettimo (Fig.1); on that island about 900 individuals were counted from 27 August to 9 September 1997 (Agostini and Logozzo pers. obs.). Young individuals, in agreement with observations made at the Falsterbo peninsula, in Sweden (Kjellen 1992), migrate later, concentrating their passage over Malta. The Honey Buzzard is the only large soaring species commonly seen in Malta, where only few Short-toed Eagles *Circaetus gallicus* and Black Kites *Milvus migrans* are observed, although both species breed in Italy (Beaman and Galea 1974).

The aim of this study is to investigate the autumn migration of Accipitriformes across the central Mediterranean, through observations on the Calabrian Apennines.

Study area and methods

Observations were carried out from 11 August to 10 October 1996. On the Calabrian Apennines few birds were observed outside of this period (Agostini and Logozzo pers. obs.). We used two observation posts on the slopes of Mount Covello and Mount Contessa at an altitude of *c.* 700 m (Fig.1), but never at the same time. The valley of River Pesipe separates Mount Covello from Mount Contessa in the west. In this area the Apennines are interrupted by a level ground between the two reliefs and the Sila plateau to the north and the Tyrrhenian and the Jonian coasts to the west and the east. We divided the two months of observation into six 10-day periods, and concentrated on the migration of adults and juveniles of the species commonly observed. It was possible to determine the age of some birds, generally when they were very close (<150 m) overhead (Agostini and Logozzo 1995b). For each species, the total of adults and juveniles was estimated according to their proportions in the sample of identified individuals, following the method used by Kjellen in his study on the autumn

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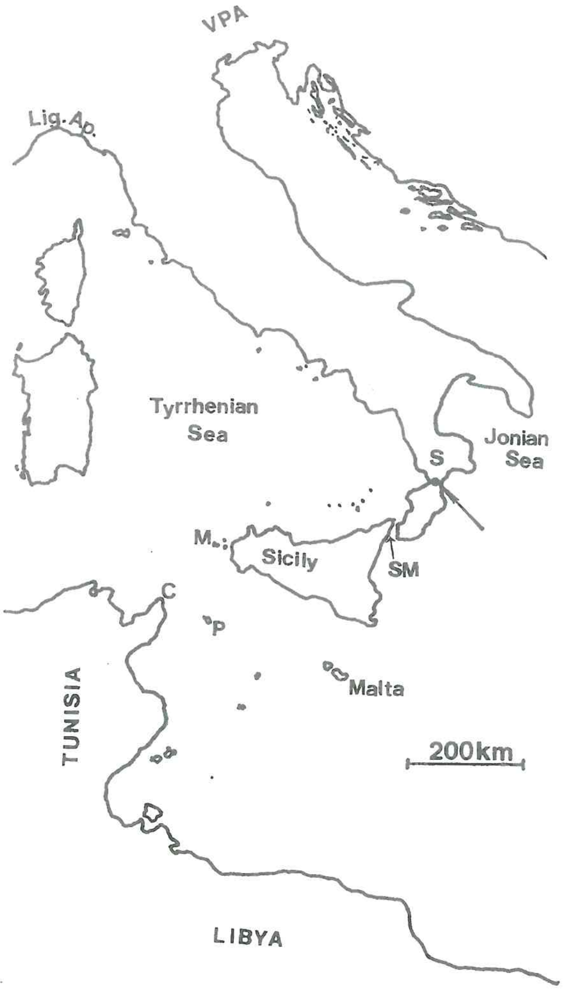

Fig. 1. Study area location (S = Sila plateau; C = Cap Bon; P = Pantelleria; M = Marettimo; SM = Straits of Messina; VPA = Venetian Pre-Alps).

migration of raptors at the Falsterbo peninsula (Sweden, 1992). The characters used in separating age were those given by Porter *et al.* (1981). Observations were made using 10x50 binoculars.

Results

A total of 2385 individuals were observed in 409 h. Because of the distance, in 182 cases it was impossible to identify the species. The most abundant species were the Honey Buzzard (1411, 64%), Marsh Harrier (460, 21%) and Black Kite (261, 12%). Moreover, we observed 41 Montagu's Harriers (*Circus pygargus*), 12 Sparrowhawks (*Accipiter nisus*), 5 Short-toed Eagles (*Circaetus gallicus*), 4 Ospreys (*Pandion haliaetus*), 3 Booted Eagles (*Hieraaetus pennatus*), 3 Egyptian Vultures (*Neophron percnopterus*), 2 Buzzards (*Buteo buteo*) and 1 Imperial Eagle (*Aquila heliaca*).

The migration of Honey Buzzards showed two peaks; the first occurred on three days from 30 August to 1 September, and the second also on three days from 5 to 7 September. The maximum number was recorded on 7 September when 247 Honey Buzzards were counted. During the first 10 days of September, a notable overlap in the migration periods of adults and juveniles occurred, while during the second and third 10 days of this month nearly all Honey Buzzards were young (Fig.2). When comparing the frequency of individuals belonging to the two age groups observed in 1993-1996 (considering the sample of identified birds), a significant difference resulted in the adults, and the proportion of juveniles was on average 25% (Table 1).

Most Marsh Harriers were observed during the first and second 10 days of September (Fig.3), with a peak of 114 individuals on 7 September. In 223 cases it was possible to observe their plumage; of these 64% were adults and 36% juveniles. Marsh Harriers and Black Kites belonging to the two age groups migrated in the same time (Figs.3 and 4). Black Kites were seen mostly during the last 10 days of August, and we recorded a flock of 79 individuals on 24 of August.

Discussion

The great difference between the counts of Honey Buzzards made on the Straits of Messina during spring and those made on the Calabrian Apennines, suggested that this route during the post-reproductive migration is used mostly by individuals breeding in central Italy (Agostini and Logozzo 1995b). By comparing the variations in the migratory flow observed on the Calabrian Apennines in 1996 with those recorded between 1992 and 1995 (Agostini and Logozzo 1995a, b, c, Agostini *et al.* 1997), a similar period of movement was observed from the end of August to the beginning of September. In contrast, the large number of adults observed during the last three years, is due to the passage of hundreds of birds at the end of the

Table 1. Young and adult Honey Buzzards identified on the Calabrian Apennines between 1993 and 1996.

	1993	1994	1995	1996	Chi-square
Honey Buzzards	895	1544	1095	1411	
Adults	149	294	197	287	64.6 P<0.01
Juveniles	69	85	67	70	2.8 n.s.

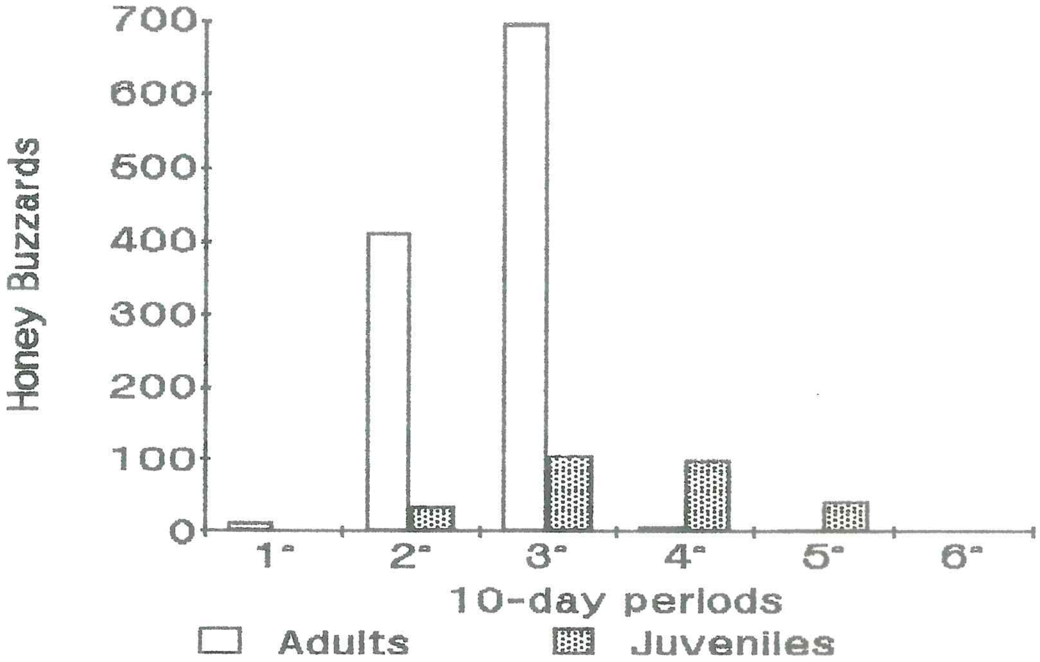

Fig. 2. Young and adult Honey Buzzards observed in six 10-day periods, according to their proportion among the identified individuals (adults n = 287, young n = 70).

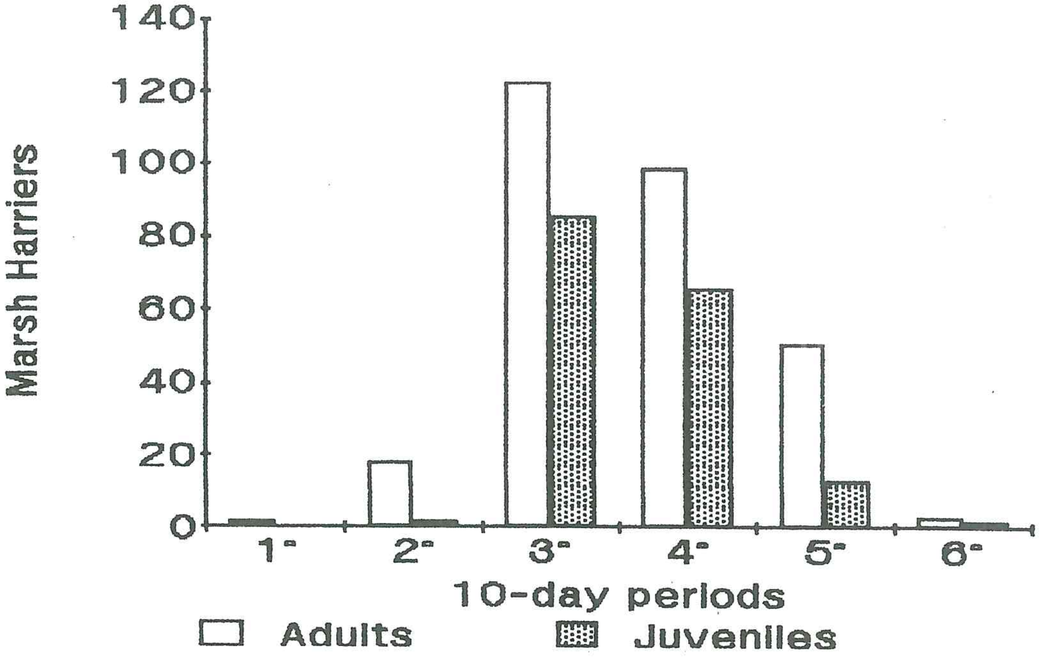

Fig. 3. Marsh Harriers (adults n = 142, young n = 81). Explanation as in Fig. 2.

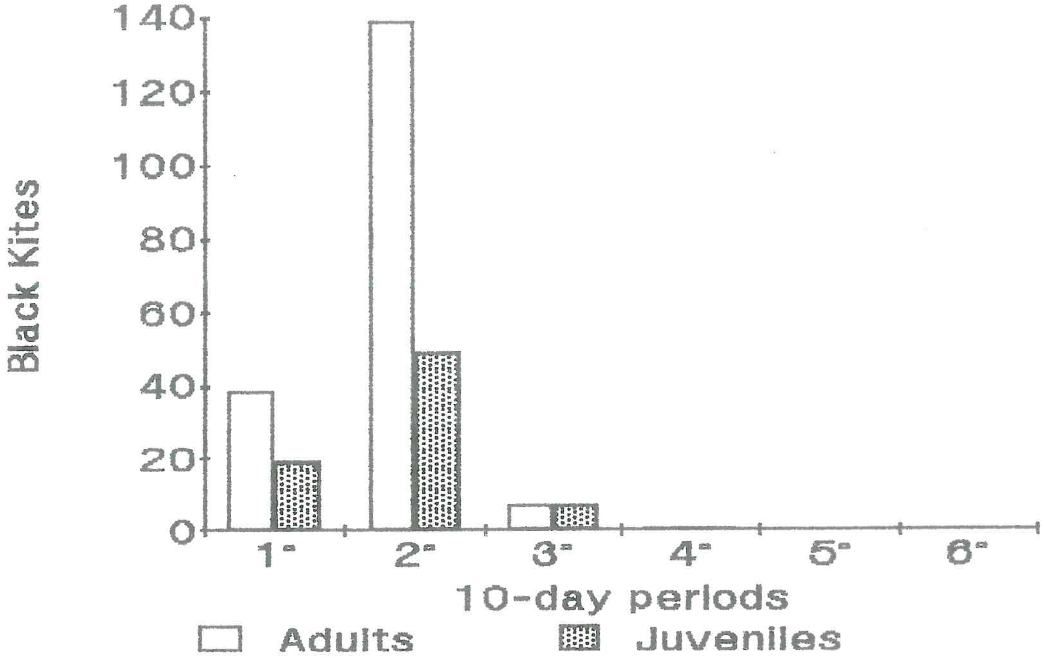

Fig. 4. Black Kites (adults n = 39, young n = 16). Explanation as in Fig. 2.

first week of September. In this period, especially in 1995 (Agostini *at al.* 1997), a significant overlap in the migration of adults and juveniles occurred. Studies made on the autumn migration of Honey Buzzards in northern Italy, suggested that there is a correlation with the movement across the Straits of Gibraltar (Mezzalira and Iapichino 1992). In the Venetian Pre-Alps (Fig.1) more than 2500 Honey Buzzards are observed passing every autumn; the peak occurred between 27 August and 2 September (Mezzalira 1991). Our observations suggest that part of the raptors migrating in this region crosses the central Mediterranean, perhaps when pushed south by unfavourable weather in the Alps, causing a "dragging" effect from juvenile individuals of central Italy. Because young observed on the Calabrian Apennines in this period do not move over Malta, it has been suggested that they are able to learn the shortest route to cross the central Mediterranean by following the adults (expert individuals) (Agostini *et al.* 1997). As in Malta, where mostly young individuals are seen (Agostini and Logozzo 1995b), a late peak is observed in Cyprus (Beaman and Galea 1974) and at the Gulf of Iskenderun, southern Turkey (Cameron *et al.* 1967). Perhaps also over these areas occurs a concentration of young Honey Buzzards. A broader front of migration during sea crossing, would also explain the low proportion of juveniles observed over the Falsterbo peninsula, Sweden (Kjellen 1992).

The Marsh Harrier is a summer resident in northern and eastern Europe, and individuals breeding in Finland cross the central Mediterranean (Gensbol 1984). These raptors have relatively long wings and, during migration, they frequently use powered flight and undertake crossings of large bodies of water (Kerlinger 1989). The number of Marsh Harriers counted on the Calabrian Appennines is similar to those observed in 1994 and 1995 over Malta (Colero *et al.* 1996), but are very different from those of a previous study made on the island between 1969 and 1973, when a maximum of only 80 individuals was observed per season (Beaman and Galea 1974). During this century the European numbers of Marsh Harriers have greatly decreased mainly because of the draining of wetlands, shooting and poisoning by pesticides. However our results are in agreement with the rapid increase which has occurred in northern Europe from 1975, probably because protection measures have been adopted (del Hoyo *et al.* 1994). Unfortunately these efforts could be frustrated by illegal hunting in Malta (Colero *et al.* 1996).

The small number of Black Kites reported, compared to the number breeding in Italy (Petretti 1992), suggests that mostly birds from southern Italy concentrate during autumn migration on the Calabrian Apennines. Black Kites cross the central Mediterranean between Sicily and Tunisia (Petretti 1992), and our observations suggest that juveniles learn this migratory route by following the adults. On 26 August 1976, about 1200 individuals were counted at Rocca Busambra (western Sicily) and 400 together were seen over the island of Pantelleria on 6 September 1978 (Fig. 1, Galea and Massa 1985, Iapichino and Massa 1989). Moreover, during the last week of August 1997, about 2000 birds were counted on the island of Marettimo (Agostini and Logozzo pers. obs.). In contrast, few birds were observed over Malta (Beaman and Galea 1974). Because Black Kites are regularly seen along the coasts and islands of the Tyrrhenian Sea (Petretti 1992), we suggest that many birds breeding in central Italy carry out long, powered flight over the sea towards western Sicily, or migrate following coastal areas.

The Short-toed Eagle is migratory in Europe, wintering in tropical North Africa (Cramp and Simmons 1980). This species mostly uses soaring flight during migration and is therefore unlikely to undertake long sea crossings (Kerlinger 1989). The main route reported passes over the Straits of Gibraltar where most birds are observed during the second half of September (Finlayson 1992). The number breeding in Italy has been estimated as 380-415 pairs, and many of them breed along the Thyrrenian slope of the central Italy (Cattaneo and Petretti 1992). Our results agree with those of previous studies made in southern Italy both during autumn and spring migration (Agostini and Logozzo 1995a, 1995c, Agostini and Malara 1997), and seem to confirm that at least birds breeding in the northern part of central Italy cross the Straits of Gibraltar, passing over the Ligurian Apennines (Fig.1, northwest Italy; Agostini and Malara 1997). Because at the beginning this route, during autumn, involves a reversed direction of migration (towards north) compared to that genetically defined, our hypothesis would suggest information transmission and thus a contemporaneous migration of adult (expert individuals) and young (inexpert individuals) (Kerlinger 1989). This species is very scarce in Malta in autumn and is not recorded in spring (Beaman and Galea 1974, Sultana and Gauci 1982). In 1993, a flock of 29 individuals was observed on 22 November which, unfortunately, were shot (Colero pers. obs.). These irregular, late movements on the central Mediterranean and observations of wintering individuals in southern Sicily (Mascara 1985), suggest that the small population breeding in southern Italy carry out short migration towards that island, crossing the sea perhaps when it becomes too numerous in relation to food availability.

With the exception of the Montagu's Harrier, the counts of the other species made on the Calabrian Apennines are similar to those reported during the spring migration at the Straits of Messina (Agostini *et al.* 1995, Agostini and Malara 1997). In fact, although Montagu's Harriers tend to migrate on a broad front (Cramp and Simmons 1980), at the Straits of Messina in 1994, 287 birds crossed at its narrowest point. During the autumn migration a notable concentration of individuals occurs at the Straits of Gibraltar where, from 11 August to 9 October 1972, 1727 were counted (Cramp and Simmons 1980). During migration over land, perhaps this species is less inclined to follow mountain chains. However, another factor could have caused the great difference between spring and autumn counts in southern Italy. Montagu's Harriers, differently from the other long-distance migrants (Kjellen 1992), apparently do not suspend molt during autumn migration (Arroyo and King 1996). These raptors fly slowly and go hunting along the way (Brown 1976, Ali and Ripley 1978). Arroyo and King (1996) suggested that this strategy allows harriers to continue molting while migrating. Gaps in the wing would involve higher energetic costs during the long powered flight across the central Mediterranean; probably, many Montagu's Harriers observed at the Straits of Messina during spring migration, choose a different route during autumn, perhaps concentrating at the Straits of Gibraltar.

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Riassunto - Sono state effettuate osservazioni sulla migrazione autunnale dei rapaci Accipitriformi sull'Appennino calabrese, dalla seconda decade di agosto alla prima decade di ottobre del 1996. Sono stati osservati 2385 rapaci, prevalentemente Falchi pecchiaioli *Pernis apivorus*, Falchi di palude *Circus aeruginosus* e Nibbi bruni *Milvus migrans*. Le osservazioni sono state concentrate sulla migrazione degli adulti e dei giovani di queste specie. I Nibbi bruni ed i Falchi di palude appartenenti ai due gruppi di età migrarono nello stesso periodo, concentrandosi, rispettivamente, durante l'ultima decade di agosto e le prime tre settimane di settembre. Queste specie utilizzano due diverse rotte per attraversare il Mediterraneo centrale; centinaia di Falchi di palude si concentrano sull'isola di Malta, mentre i Nibbi bruni attraversano il mare nel suo punto più stretto, tra la Sicilia e la Tunisia. Nel caso del Falco pecchiaiolo, una parziale sovrapposizione dei periodi di migrazione degli adulti e dei giovani è stata rilevata durante la prima decade di settembre. Le nostre osservazioni suggeriscono che almeno parte della popolazione di Biancone *Circaetus gallicus* nidificante lungo il litorale tirrenico dell'Italia centrale, non utilizzi questa rotta migratoria. Probabilmente questi uccelli attraversano il Mediterraneo sullo Stretto di Gibilterra, passando sull'Appennino ligure. Questa ipotesi implicherebbe trasmissione delle informazioni tra gli adulti (individui esperti) ed i giovani (individui inesperti).

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Impact of the feeding habits of the Great Cormorant *Phalacrocorax carbo sinensis* on the lagoon fish-stocks in central-western Sardina

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Abstract - The constant growth of the Cormorant wintering population is causing serious damage to Sardinian lagoon fish-stocks. This report presents an evaluation of the feeding patterns of the species made on the basis of stomach content analysis. The resulting economic damage in central-western Sardinia is also estimated.

Introduction

Given the widespread presence of lagoons and ponds throughout its territory, and the quality of their waters, Sardinia has become one of Italy's most important wintering areas for many bird species.

In 1977 the Italian government assigned to Sardinia 8 wetlands of 12,649 ha, according to the Ramsar Convention was ranked second in Italy, immediately after Emilia Romagna, as region of international importance.

These wetlands are important not only for the large variety of bird species that breed and winter there but also for fishing which is one of the main economic and traditional activities in the island.

Among the most common species present in the area, the Great Cormorant, *Phalacrocorax carbo sinensis* is of great biological interest for its feeding behaviour and for its possible interactions with fish-farming. While in the past the feeding habits of the cormorants were overlooked as the population was relatively small, in recent years there has been a steady increase in the numbers of birds wintering in Sardinia and their interaction with the lagoon resources is causing growing concern among the fishermen.

Given the favourable environmental characteristics of the island, indeed, starting from 1987 there has been a constant rise in the population of wintering birds which reached the highest density at the national level especially in the years 1993 (12000 individuals), 1994 (10040) and 1995 (12664) (Regione Autonoma Sardegna, 1993; Baccetti and Cherubini, 1995).

This phenomenon has prompted studies to evaluate the size of the population (Mocci Demartis, 1991 - Regione Autonoma Sardegna, 1993, 1994) and to determine the impact of this species on the lagoon fish-stocks (Cau *et al.*, 1991).

The latter aspect which has been extensively debated at the national (Baccetti and Corbi, 1988; Cherubini *et al.*, 1993; Volponi, 1995) and international level (Lindell, 1989; van Eerden and Zijlstra, 1989; Marteijn and Dirksen, 1989; Mellin and Martyniak, 1989; Suter, 1995; Voslamber *et al.*, 1995; De Nie, 1995) has required special attention for Sardinia because of the twofold need of characterizing the feeding habits of the species and making a more reliable assessment of the very large numbers of wintering birds. The results of a two-year investigation are presented here, with emphasis the qualitative/quantitative aspects of the feeding habits of the Cormorant.

Study Area

The investigation was carried out in the lagoons and ponds of Central Western Sardinia (Oristano) and in particular in:

	Lagoon	Area (ha)	Water depth m. (min-max)
A	San Giovanni	290	0,40 - 1
B	Corru S'Ittiri	150	0,50 - 1
C	Marceddì	1270	1 - 2
D	S'Ena Arrubia	190	0,40 - 2
E	Cabras	2228	0,40 - 3

According to the 1993 census (Regione Autonoma Sardegna, 1993) these areas host approximately 65% (7800 individuals) of the wintering Cormorant population of Sardinia, estimated for that year to be around

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Tab. 1

	year	mean	Mullets	Eels
		Kg/ha/year	Kg/ha/year	Kg/ha/year
Cabras lagoon	1984-89	290	203.5	21.2
S. Giovanni-Marceddì lagoon	1985-89	589	60	122
Corru S'Ittiri lagoon	1985-89	376	55	36.3
S'Ena Arrubia lagoon	1976-78	428	203.5	21.2

12.000 individuals for the whole Sardinia. For that same area the 1987 figure calculated by Baccetti and Corbi (1988) was about 1100 cormorants and for 1988 it was around 2000 (Ravasini, Pinna in Baccetti & Corbi, 1988); the same value was also found for 1990 (Mocci Demartis, *pers. comm.*). Therefore between the late 1980s and the past two years there has been an increase of around 350%.

The following figures reflect the fishing production in the coastal ponds in terms of annual income per hectare (Kg/ha/year) according Rossi and Cannas (1992) (cf. Table 1).

The fish species mostly present are grey mullets (*Liza ramada, Liza saliens, Mugil cephalus*), the sparids (*Diplodus sargus, Diplodus puntazzo, Diplodus vulgaris, Sparus aurata*), and in particular the eels (*Anguilla anguilla*). Among Crustacean, *Palaemon serratus* is the most important species produced.

The environmental and climatic characteristics of the region, the large areas of shallow waters and the availability of fish cause this area to be an ideal place overwintering cormorants (van Eerden and Munsterman, 1986).

Methods

Our study is based on the stomach content analysis of 104 cormorants (48 immatures, 56 adults; total sex ratio 1.2) obtained from two shooting campaigns which had been planned by the local Authorities (Department for Environmental Protection) and carried out under the strict control of the State Forestry Service (cf. Table 2).

Although samplings were carried out in distinct areas will be difficult to correlate the feeding to a particular area because the lagoons are in continuity or very close each other so the cormorants' flocks can commute between them preying the fish in a wide region.

Tab. 2

	1991		1992	
	lagoon	cormorants	lagoon	cormorants
January	ABCDE	13		
February	ABCDE	43	C	18
April	ABCDE	30		
Total		86		18

For the 1991 specimens, the shooting campaign was carried out in three different time periods (before 7.30^{h}; 10.30^{h}-15.00^{h}; after 17.00^{h}) to be able to take possible trends, in the predatory activity into account.

Integral prey and unidentified residuals found in each stomach were weighed and prey counted. Where possible the species of the prey were identified, while for integral specimens Total Length and Total Weight were measured. Any parasites found in the gastric tract were also recorded.

The data were processed using the mixed numerical-ponderal system suggested by Hureau (1970). This author considers a variety of parameters such as reported in Table 3.

As showed above Q is the combination of Numeric and Ponderal composition (in percentage) of the diet.

On the basis of Q value, prey can be classified as being Preferential, Secondary and Accidental (cf. Table 4).

This parameter is the most indicative because looking at C_n and C_w separately they couldn't give a proper description of the diet. In fact we could get the same Q value for different preys although they have a different impact in the numerical or ponderal diet composition (high % in number and low in weight or low % in weight and high in number). But Q cannot show how

Tab. 3

V =	Vacuity index:	Empty stomachs x 100/total examined stomachs
f =	Prey frequency index:	number of stomachs with prey spi / total number of examined stomachs
C_n =	% of prey in numbers:	Number of prey spi x 100/total number of preys
C_w =	% of prey in weight:	Weight of prey spi x 100/total weight of preys
N_{avg} =	average prey per stomach	Total number of prey/number of examined stomachs
W_{avg} =	average weight per stomach	Total weight of prey/number of examined stomachs
Q =	Food coefficient:	C_N x C_W

Where: sp_i = species a, b, c.....i

Tab. 4

Definition	Q
Preferential prey	Q > 200
Secondary prey	20 < Q < 200
Accidental prey	Q < 20

the prey are distributed in all the stomachs analyzed, then, to obtain the "recurrence" of a prey spi in the sample we use the "f" parameter. The values of Hureau's analysis were used to obtain the daily consumption, that applied to the size of the wintering population for 1991 and 1993 were useful to estimate of the total daily biomass.

The censuses indicated some 2000 birds in 1990/91 (Mocci Demartis, *pers. comm.*) and 7840 in 1992/93 (Regione Autonoma Sardegna, 1993); the figures refer to birds counted in January-February, because monthly census were not available.

Results

A detailed analysis of the stomach contents showed the overall presence of 25 species of fish and of the *Palaemon* genus among the Decapod Crustaceans (*=Commercial Species) (cf. Table 5).

Numerically the most abundant prey were *G. niger*, *A. fasciatus*, *Atherina sp.* in both 1991 and 1992. In terms of weight the prey of the *Liza* genus prevailed in the two years (see Tables 8-11).

The large number of prey belonging to this genus and the trend of the size/frequency histograms made it possible to determine the fraction which is subtracted from the fishing industry and the amount that could be fished if not preyedon (Fig. 1). Indeed, the histogram of the size frequencies (in absolute number) shows that the fish longer than 16 cm, minimum size eligible for being fished, according to EEC Regulation n.1626/94 of 27/06/94, are about 70% for 1991 and 80% for 1992. Preyed mullets ranged from 12 to 30 cm of total length in both years with a modal class of 18 cm. According to Cau (1994) the value of the modal class for *Liza ramada*, fished in the Cabras lagoon area, is 26-28 cm of total length with a captures range varying from 18 to 36 cm using a gill-net n.10 mesh sized (Fig. 2).

These data (that need further confirmation) evidence that the most cormorants' catches weigh on the length classes of which represent the recruitment for the lagoon exploited stock.

The calculation of the parameters of the feeding pattern over a 24 hour period shows, on the basis of the value of Q, that in 1991 *G. niger* (Q=342) and *Liza sp.* (Q=341) were the ones most preferred (Preferential), whereas in 1992 *Liza sp.* (Q=1968) were Preferential prey over several Secondary and Accidental preys (Tables 8-11).

In 1991 the prey frequency index "f" for mullets was 45.5% followed by prawns with 30%, black goby 21%. In 1992 mullets were recorded in the 67% of shooted cormorants, killifish and sand-smelts in the 11%.

The preying activity indicated by the progression of the vacuity index, appears to increase throughout the day, as illustrated below:

– for captures before 7.30^h, V = 100% (n=8); 10.30-15^h, V = 32% (n =40); after 17.00^h V = 8% (n=56).

This figure, together with the weight increase of stomach content (W_{avg} = 152g.) found for the animals captured during the second and third time periods, and considering that 90% of the animals captured between 17.00^h and 19.30^h presented extensive traces of fish that had been partially digested, both in the intestinal tract and in the lower part of the stomach, suggest that this species feeds at least twice a day. So the daily consumption was assumed of about 300g.

Tab. 5

Fish					
1)*	*Anguilla anguilla*	Eel	14)*	*Liza saliens*	Leaping mullet
2)	*Aphanius fasciatus*	Killifish	15)*	*Mugil cephalus*	Flathead grey mullet
3)*	*Atherina sp.*	Sand Smelts	16)*	*Sardina pilchardus*	European pilchard
4)	*Blennius pavo*	Peacock blenng	17)*	*Sarpa salpa*	Salema
5)	*Cyprinus carpio*	Carp	18)*	*Solea vulgaris*	Common sole
6)*	*Dicentrarchus labrax*	Seabass	19)*	*Sparus aurata*	Gilthead seabream
7)*	*Dicentrarchus punctatus*	Spotted seabass	20)	*Symphodus rostratus*	Wrasse
8)*	*Diplodus sargus*	White seabream	21)	*Symphodus tinca*	Peacock wrasse
9)*	*Diplodus annularis*	Annular seabream	22)	*Symphodus ocellatus*	Ocellated wrasse
10)*	*Engraulis encrasicolus*	Anchovy	23)	*Symphodus roissali*	Five-spotted wrasse
11)*	*Gobius niger*	Black goby	24)	*Sygnathus abaster*	Pipefish
12)*	*Liza aurata*	Golden grey mullet	25)	*Syngnathus typhle*	Deepsnouted pipefish
13)*	*Liza ramada*	Thinlip mullet			
Crustaceans					
26)*	*Palaemon sp.*	Prawns			

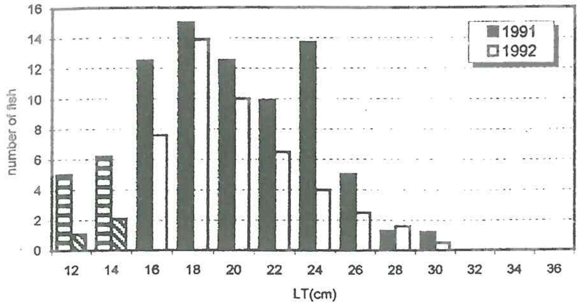

Fig. 1. Length frequency of Mullets founds in the stomach contents (in the dotted lines not commercial sizes).

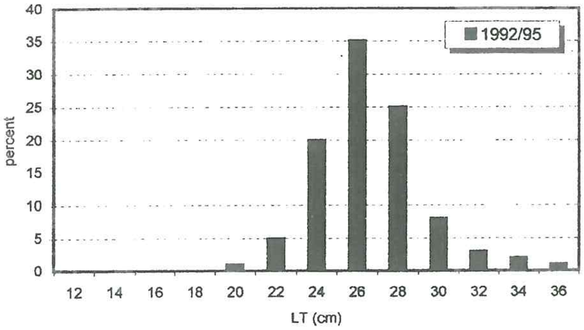

Fig. 2. Length frequency of *L. ramada* from commercial fishing of Cabras lagoon (Cau 1994).

Parasites

The 15% of the birds (N = 104) had parasites in their gastric tract. The helminths analysed were found to belong to the *Contracaecum* genus (Nematoda: Ascaridida), confirming the observations made by d'Amelio *et al.* (1991) on cormorants from the Circeo National Park.

Places of Origin

The presence of ringed birds highlighted the heterogeneous nature of the Sardinian overwintering population in terms of geographic areas of origin. Birds ringed in Sweden, Denmark, Holland, former Yugoslavia and Germany confirm the assumption made by Van Eerden and Munsterman (1986) on the migratory flyway from Northern Europe (birds ringed in Poland were not reported) and the survey of past ringing data from Sardinia (Mocci Demartis, 1991).

Assumptions on the Prey Load

On the basis of field observations and the analyses of the stomach contents, and as confirmed also by other authors (Im and Hafner, 1984; Builles *et al.*, 1986), the wintering population of the Oristano's lagoon tended to feed twice a day. This suggests that the average daily biomass preyed is just over 300 g. The total daily biomass preyed on by the population was calculated by extrapolating the data from Hureau's analysis on the percentage species composition of the stomach contents for 1991, by assuming the average daily intake as being around 300 g, and by applying this value to the whole wintering bird population counted in January 1991 and 1993.

TOTAL DAILY BIOMASS = Daily Consumption x Number of Cormorants.

Considering a wintering period of 180 days of the cormorant population, we estimated the amount of fish stock consumed per season as to be over 55 kg per individual bird.

According to the average species composition in 1991, 40% of the fish consumed consists of the *Liza* genus for an amount equivalent to 22 kg/season, and the size frequency analysis (see Fig. 1) indicates that over 15 kg of this amount is of immediate commercial value whereas the remaining 7 kg could be the following months.

In fact, considering the growth parameters and the size/weigth relationship proposed for the *Liza* genus by Farrugio and Quignard (1974) and the natural mortality (wich is low for the adults in the lagoon, Chauvet, 1988), these 7 Kg, belonged to the 12 and 14 cm class, would reach the commercial size after 3.8 and 2 months respectively (Table 6).

Therefore, in the predation evaluation, has importance not only the estimate biomass, but also the biomass increment defect that result of the predation of the not recruited individuals.

Discussion

A) As indicated in the literature, the Cormorant is a fish-eating species and opportunistic in terms of diet. Indeed they do not prefer one species in particular but they capture the fish that are more abundant and that are easier to catch.

The largest proportion of the cormorants' food intake is represented by the Mugilidae and in particular *Liza ramada*, *Liza saliens* and *Mugil cephalus* species (Mullets), because they are particularly abundant in the lagoons (according to data from Rossi and Cannas, 1992), they have a gregarious behaviour and they live close to the water surface.

According to our observations Cormorant's flocks fly over the pond's surface causing the assemblage of the mullets in thick crowds and then prey easily the fish.

In terms of number but not of weight, given the small weight of the species, the Black goby *Gobius niger* is an important part of the diet of the cormorants.

Tab. 6 - Parameters of the Von Bertalanffy equation and of the size/weight relationship for *L. ramada* (Farrugio, 1974), and biomass increment in the non-commercial size class.

L_∞	k	t_0	a	b	M
39.6	0.49	-0.06	-1.9	2.89	0.2

LT (cm)	Age (months)	Individual Weight (g)	Time to comm. size	Number of fish at comm. size	Total Weight at comm. size
	From Von Bertalannfy eq.	$W = b L^a$	Months	From Mortality model	Kg
12	8.12	38.86	3.83	73.16	4.91
14	9.96	52.09	1.99	73.71	4.95
16*	11.96	67.13			9.86

* commercial size

This is closely related to the large biomass of brackish environments and in particular where the waters are shallow, stagnating and with muddy beds full of detrital material. The same holds for the *A. fasciatus* species.

Among the other species of fish present in the diet of the cormorants, mention can be made also of eel *A. anguilla*, but not in large amounts given their nocturnal and digging habits which makes them difficult to be caught (Martucci and Consiglio, 1991), seabasses *Dicentrarchus sp.*, seabreams *Diplodus sp.* that are classified as accidental prey. It is worthwhile to mention the presence of pipefish *S.abaster* and deep-snouted pipefish *S.typhle* for which there is little information in the literature.

Among the Decapod Crustaceans, the *Palaemon* genus with the *elegans* and *serratus* species (Prawns) represents a major share of the cormorants' diet. Indeed, in 1991 they accounted for 10.5% (1.3 in 1992) in terms of the number of prey uptake (Tables 8-11). This confirmed the observations by Barret *et al.* (1990) about the presence of crustaceans (brachyurans) in the cormorants' diet and Hold-Mortensen (1995), according to whom Palaemons are a significant part of the cormorant's diet. Finally by fitting Hureau's parameters it was found that in 1991 and in 1992 the average number of prey found (N_{avg}) are as in Table 7.

These values should be higher if we consider the fact that the undeterminate food component (recorded in the lower part of the stomach and in the enteric tract) is equal to 32.9% in 1991 and to 22.5% in 1992 (Tables 8-11).

B) On the basis of the quantitative analysis of the stomach contents (152g) and of the daily trophic ryhthms, the average daily biomass rate has been estimated to be about 300 g. Our findings differ significantly from those of other investigators:

- Madsen and Spark (1950) and Van Dobben (1952) estimate the "Daily Diet Rate" as being 750 g;
- Barret *et al.* (1990) estimate the daily diet to be about 661 g;
- Cramp and Simmons (1977) consider the daily diet as being 15-17% of the body weight, namely 400-700 g;
- Linn and Campbell (1986) estimate the daily diet as being 12-15% of the body weight, namely 250 g;

On the contrary our data seem to be in close agreement with those obtained by: Voslamber (1988) (234-360 g/day from pellet analyses); Marteijn and Dirksen (1989) (310 g/day from pellet analyses); Volponi (1995) 343 g/day.

It must be pointed out however that in some productive waters rich in fish, (for instance the Cabras lagoon), *Liza ramada* fish of over 600 g were found and in one case a cormorant was found to have two Mugil cephalus fish weighing over 1000 g.

The total amount of biomass consumed in the Oristano region was estimated to be around 110 tons for 1990-1991, the year when the cormorant population was found to be 2000, and 432 tons for 1992-1993 when according to the census the figure was about 7800 individuals. The fact that the wintering cormorants feed on an area of about 5600 ha (relative to the entire Oristano's area) during 180 days, suggests that the biomass

Tab. 7

Year	Black gobies	Killfishes	Mullets	Pipefishes	Prawns	Anchovy	Smelts	Total
1991	6.6	2	1.7	1.7	1.5	1		14.5
1992		6.2	3.8				1.3	11.4

consumed per hectare is around 19.8 kg/ha for 1991 and of about 77 Kg/ha for 1993. The latter value is undoubtedly much higher than the marine coastal production which is estimated to be about 41 Kg/ha/year and is very close to the maximum production of around 70% of the Mediterranean lagoons for which a yield of between 10 and 80 Kg/ha/year was measured by Chuavet (1988).

Tab. 8. 1991 - Stomach contents and Hureau parameters in the hour range 10,30-15,00 (N=22).

	Number	Weight(g)	Cormorants	f (%)	C_n (%)	C_w (%)	Q
FISH							
A. anguilla	1	157	1	4,5	0,4	7,7	3
A. fasciatus	8	12	2	9,1	2,8	0,6	2
B. pavo	1	6	1	4,5	0,4	0,3	
E. encrasicholus	70	129	4	18,2	24,6	6,3	156
G. niger	79	118	2	9,1	27,8	5,8	160
L. ramada	11	497	4	18,2	3,9	24,3	94
L. saliens	9	416	3	13,6	3,2	20,3	65
S. abaster	61	55	2	9,1	21,5	2,7	56
CRUSTACEANS							
Palaemon sp.	44	45	5	22,7	15,5	2,2	34
UNDET.		664	22	100,0		32,5	
TOTAL	284	2099					
N_{avg}=18,9			W_{avg}=136g			V=31,82%	

Tab. 9. 1991 - Stomach contents and Hureau parameters in the hour range 17,00-19,30 (N=56).

	Number	Weight(g)	Cormorants	f (%)	C_n (%)	C_w (%)	Q
FISH							
A. anguilla	9	481	4	7,1	1,3	6,2	8
A. fasciatus	122	224	7	12,5	17,9	2,9	52
B. pavo	2	32	2	3,6	0,3	0,4	
B. salpa	3	376	2	3,6	0,4	4,9	2
C. carpa	5	403	3	5,4	0,7	5,2	4
D. annularis	2	11	2	3,6	0,3	0,1	
G. niger	361	613	12	21,4	53,1	8,0	423
L. ramada	34	1645	12	21,4	5,0	21,3	107
L. saliens	28	1346	11	19,6	4,1	17,5	72
S. abaster	45	31	4	7,1	6,6	0,4	3
S. ocellatus	1	50	1	1,8	0,1	0,6	
S. roissali	1	50	1	1,8	0,1	0,6	
S. rostratus	5	30	1	1,8	0,7	0,4	
S. tinca	2	43	1	1,8	0,3	0,6	
S. typhle	3	3	1	1,8	0,4	0,0	
CRUSTACEANS							
Palaemon sp.	57	65	15	26,8	8,4	0,8	7
UNDET.		2356	56	100,0		30,6	
TOTAL	680	7757					
N_{avg}=13,3			W_{avg}=151g			V=8,93%	

Tab. 10. 1991 - Stomach contents and Hureau parameters during 24h (N=86).

	Number	Weight(g)	Cormorants	f (%)	C_n (%)	C_w (%)	Q
FISH							
A. anguilla	10	638	5	7,6	1,0	6,5	7
A. fasciatus	130	236	9	13,6	13,5	2,4	33
B. pavo	3	38	3	4,5	0,3	0,4	
B. salpa	3	376	2	3,0	0,3	3,9	1
C. carpa	5	403	3	4,5	0,5	4,1	2
D. annularis	2	11	2	3,0	0,2	0,1	
E. encrasicholus	70	129	4	6,1	7,3	1,3	10
G. niger	440	731	14	21,2	45,6	7,5	342
Liza sp.	82	3903	30	45,5	8,5	40,0	341
Symphodus sp.	9	173	4	6,1	0,9	1,8	2
Syngnathus sp.	109	89	7	10,6	11,3	0,9	10
CRUSTACEANS							
Palaemon sp.	101	110	20	30,3	10,5	1,1	12
UNDET.		3206	86	100,0		32,9	
TOTAL	964	10041					
N_{avg}=14,6			W_{avg}=152,1g			V=23,26%	

Tab. 11. 1992 - Stomach contents and Hureau parameters during 24h (N=18).

	Number	Weight(g)	Cormorants	f (%)	C_n (%)	C_w (%)	Q
FISH							
A. fasciatus	81	43	2	11,1	52,9	1,8	94
Atherina sp.	17	32	2	11,1	11,1	1,3	15
D. labrax	1	123	1	5,6	0,7	5,1	3
D. punctatus	1	63	1	5,6	0,7	2,6	2
D. sargus	1	88	1	5,6	0,7	3,7	2
Diplodus sp.	1	35	1	5,6	0,7	1,4	1
Liza sp.	49	1471	12	66,7	32,0	61,4	1968
CRUSTACEANS							
Palaemon sp.	2	2	1	5,6	1,3	0,1	
UNDET.		538	18	100,0		22,5	
TOTAL	153	2394					
N_{avg}=11,8			W_{avg}=185g			V=28%	

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A good start in life: influence of parental quality on breeding and survival in the Cory's Shearwater *Calonectris diomedea borealis*

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Abstract - In the Cory's Shearwater *Calonectris diomedea borealis* of Selvagem Grande (30°09'N, 15°52'W), successful first time breeders lay subsequently more often than their unsuccessful congeners, and their eggs, bigger, have a better success. These better results have no baneful influence on their survival, higher on average than that of their congeners and so, they can fledge, during their life, 65 % more chicks. This skill is not inherited - it is absent when the chicks fledge and the survival at sea is independent of parental skill - but apparently learned during immaturity and during the very first breeding years.

Introduction

Among seabirds generally, and among Procellariiformes in particular, breeding frequency and breeding success are influenced by many factors, some of which have been well studied – especially the age and experience of breeders – and others far less well. This is particularly true for parental « quality », in other words their peculiar skill independently of all the other factors. So we have taken advantage of our sojourns on Selvagem Grande (30°09'N, 15°52'W) to test the influence of this parameter on the breeding and survival of one of the procellariids of the island, the Cory's Shearwater *Calonectris diomedea*. We had three main objectives. First we wanted to know if some birds were able, systematically and during all their life, to lay more eggs and rear more chicks than other birds similarly aged and experienced. Second, if such a skill existed, was it learned by the birds or inherited from their parents and, third, had it an influence on their survival?

But how was it possible to distinguish a high quality from a low quality bird? Previously, the problem had been approached by various ways. Comparisons had been made between birds laying bigger eggs than average and birds laying smaller eggs (Amundsen and Stokland 1990). Among species laying more than one egg, birds laying more eggs than average had been compared with birds laying less eggs (Coulson and Porter 1985). For us, we have thought that it would be better to take the birds at the beginning of their breeding life and to compare successful with unsuccessful first time breeders, assuming that the success of the first breeding attempt was not a matter of chance but already a characteristic of high quality birds, and that other differences were likely to be apparent later on, in egg size, breeding success, breeding frequency, adult survival and parental skill. The results of these comparisons are exposed in the following pages.

Methods

The study has been carried out since 1978 in two colonies and since 1980 in a third, involving a little less than 500 nest sites since the end of the eighties. All the nests and all the adults are marked or checked and all the eggs laid censused during visits paid every year to the colonies in June, during incubation. Thus, the year of first breeding and, later on, breeding frequency and breeding experience are known for most birds. Sex is determined by bill measurements - only 10% of paired birds cannot be sexed by this method (Mougin *et al. 1986*). To avoid unnecessary disturbance, the birds are handled only once each year, and one bird at each nest is marked with picric acid on the breast to differentiate it from its mate. Chicks are censused – which allows the estimation of breeding success – and ringed in September-October, shortly before they fledge. A sample of chicks has been ringed every year between 1968 and 1971 and every year again since 1977. Some of them have already returned to Selvagem Grande to breed. Their age and the iden-

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tity of their parents are thus known. Adult survival has been estimated following Cormack (1964) and egg size using the volume index Lb^2 where L is the length and b the breadth. For statistical calculations, Student's t-test and X^2 have been used and some correlations have been made.

Results

A comparison of data related to breeding and survival in successful and unsuccessful first time breeders is presented in table I.

During the first breeding attempt, the egg volume index of the successful breeders is higher than that of the unsuccessful individuals (185.0 *v* 172.0). Later on, the difference between successful and unsuccessful first time breeders lessens but is still significant (189.4 *v* 185.0).

During the second breeding year, the success of the birds having succeeded during their first attempt is significantly higher than that of the birds having failed (0.595 *v* 0.516). Later on, success increases with experience in both groups, but is always lower among the second than among the first and, on average, for all the breeding years except the first, successful first time breeders achieve better results than their unsuccessful congeners (0.641 *v* 0.586) Thus, egg and chick mortality is on average 15.4% higher among the second ones than among the first (12-19% according to experience).

The success of the first breeding attempt increasing with age ($r_6 = 0.841$, $P < 0.05$, between 6 and 11 years), the better results shown by some birds could have been linked to an older age. However this is not the case. During the first attempt, successful and unsuccessful breeders are similarly aged (9.0 *v* 8.8 years). Besides, for any age of first breeding, the subsequent success of the successful birds is always higher, significantly or not, than that of the unsuccessful similarly aged individuals (X^2_1 varying between 0.001, n. s., and 6.4, $P < 0.05$).

The mates of the successful first time breeders are on average more experienced that those of the unsuccessful birds (5.4 *v* 4.6 years), and the proportion of inexperienced birds among them is lower - respec-

Tab. I. Influence of parental quality (as shown by the success of the first breeding attempt) on breeding and survival in the Cory's Shearwater of Selvagem Grande. Mean ± SD (sample size). n.s: not significant; ** $P < 0.05$; *** $P < 0.01$.

	Birds whose first breeding attempt was			
	successful	unsuccessful	X^2	t
Egg volume index				
- First breeding attempt	185.0 ± 12.6 (22)	172.0 ± 17.7 (37)	-	***
- Others	189.4 ± 13.1 (94)	185.0 ± 10.8 (103)	-	***
Breeding success				
- Second breeding attempt	0.595 (301)	0.516 (314)	**	-
- Others	0.653 (1196)	0.608 (1027)	**	-
- Total	0.641 (1497)	0.586 (1341)	***	-
Age at first breeding (years)	9.0 ± 1.6 (110)	8.8 ± 1.7 (137)	-	ns
Experience of the mate (years)				
- First breeding attempt	5.4 ± 4.2 (605)	4.6 ± 4.3 (551)	-	***
- Fifth breeding attempt	7.8 ± 4.5 (179)	7.3 ± 4.6 (159)	-	ns
Breeding frequency	0.831 (1471)	0.802 (1303)	**	-
Annual survival rate	0.9547 ± 0.1054 (12)	0.9414 ± 0.1092 (12)	-	ns
Breeding success of parents				
- Male	0.732 (355)	0.754 (472)	ns	-
- Female	0.716 (401)	0.686 (538)	ns	-
- Both sexes	0.724 (756)	0.718 (1010)	ns	-
Breeding frequency of parents				
- Male	0.884 (500)	0.891 (700)	ns	-
- Female	0.905 (558)	0.893 (776)	ns	-
- Both sexes	0.895 (1058)	0.892 (1476)	ns	-
Annual survival rate of parents	0.9546 ± 0.0919 (17)	0.9507 ± 0.0551 (17)	-	ns

tively 0.291 *v* 0.396 ($X^2_1=14.1$, $P < 0.01$). Later on, following deaths, divorces and rematings, this difference disappears.

The breeding frequency of the successful first time breeders is higher than that of their unsuccessful congeners - 0.831 *v* 0.802, which corresponds to a 17.4% excess of sabbatical years among the second.

The annual survival rate of the successful first time breeders is higher, although not significantly, than that of their unsuccessful congeners - 0.9547 *v* 0.9414, which corresponds to a 29.4% difference in annual mortality (respectively 4.5 *v* 5.8%) and to a 5.0 years difference in average longevity (respectively 21.6 *v* 16.6 years).

Thus, with a breeding success of 1.0 for the first attempt and of 0.641 for the others, against 0 and 0.586, a breeding frequency of 0.831 against 0.802 and a longevity of 21.6 years against 16.6, the successful first time breeders will produce during their life 35% more eggs and 65% more fledgings than their unsuccessful congeners.

Among the chicks of the birds whose first breeding attempt has been observed, the proportion of those whose parents were then successful is the same among fledgings and first time breeders - 0.689 (n = 791) *v* 0.702 (n = 67), $X^2_1 = 0.05$, n.s. Thus, during immaturity, the young of good quality birds do not survive better than those of low quality birds. Survival during immaturity is independant of parental skill.

The average breeding success of the parents of successful and unsuccessful first time breeders is the same - 0.724 *v* 0.718. Likewise, no correlation exists between the average success of descendants and parents, male ($r_{63} = -0.132$, n.s.) or female parent ($r_{60} = 0.109$, n.s.) being taken into account. Breeding frequency is also the same in both cases (0.895 *v* 0.892) as is the annual survival rate - 0.9546 *v* 0.9507, a not significant difference of 8.6% in annual mortality and of 1.7 years in average longevity.

Discussion

In the Cory's Shearwater of Selvagem Grande, the success or failure of the first breeding attempt, carried out by inexperienced birds, could have been a matter of chance. But it is not and a good start in breeding life is one of the characteristics of the highly qualified breeders. In fact, these successful first time breeders lay more often than their congeners during the following years, and their eggs, bigger, have a better success. These better results have no baneful influence on their survival, higher on average than that of their congeners, and so, they can fledge, during their life, 65% more chicks. This skill doesn't seem to be inherited – it is indeed absent when the chicks fledge and their survival at sea is independent of parental skill – but apparently learned during immaturity, from the first returns to land, and during the very first breeding years. Age and experience being equal, some birds are thus more able than others, and that better quality is apparent from the first breeding attempt.

These results are surprising. The more frequent laying of bigger eggs, and the fledging of more chicks should involve a stronger strain likely to be paid by a lower survival. Anyway, this is not the case. The skill acquired by some birds allows them to produce more at a lesser cost and thus they don't jeopardize their subsequent survival. On the contrary, through working harder and finishing breeding in poorer condition, low quality birds suffer a greater cost in terms of longer intervals between successive breeding attempts and consequently reduced survival. Similar results are shown by Kittiwakes *Rissa tridactyla* (Coulson and Porter 1985). With good environmental conditions, the birds which lay 3 eggs rear more youngs and have a better survival than those which lay 2 or 1 egg only. Incidentally, these results can be altered by adverse conditions. In this species and in others (Chastel *et al.* 1993, 1995, Coulson 1984, Drent and Daan 1980, Prince 1985), when the survival of the birds could be endangered by difficult conditions, they miss a breeding season, or lay a smaller clutch, or fledge less chicks. Survival stability implies then a decrease of breeding frequency and breeding success. Anyway, these results concern whole populations. Efficient birds probably obtain still better results than others.

Thus, rearing more chicks during their life, the most able Cory's Shearwaters of Selvagem Grande contribute more than the other birds to the present increase of the breeding numbers, considerably depleted during the seventies. But they do not bequeath their qualities to their progeny and the average level of the population is thus not appreciably improved.

Résumé - Chez le Puffin cendré *Calonectris diomedea borealis* de Selvagem Grande (30°09'N, 15°52'W), les oiseaux qui réussissent leur première reproduction pondent par la suite plus souvent que leurs congénères qui ne l'ont pas réussie, et leurs oeufs, plus volumineux, montrent une meilleure réussite. Ces meilleurs résultats n'ont pas d'influence néfaste sur leur survie, plus forte en moyenne que celle de leurs congénères, et ainsi ils peuvent élever, pendant leur existence reproductrice, un surplus de 65% de poussins. Cette compétence n'est pas héritée – elle est absente quand les poussins terminent leur croissance, et leur survie en mer est indépendante des capacités des parents – mais probablement apprise pendant la période d'immaturité et pendant les toutes premières années de reproduction.

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