INFLUENCES OF AGRICULTURAL LAND-USE AND HABITAT MODIFICATION ON THE BREEDING BIOLOGY AND CONSERVATION OF COLLARED PRATINCOLES *Glareola pratincola* IN SW SPAIN

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CANDIDATE'S DECLARATION

I declare that the work recorded in this thesis is entirely my own, unless otherwise stated, and that it is of my own composition. No part of this work has been submitted for any other degree.

Belén Calvo
September 1993

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SUMMARY

1. The marshes of the Guadalquivir river and other wetlands in southwest Spain (study area) have been widely reclaimed for agriculture. One of the bird species affected by this land-use policy is the Collared pratincole *Glareola pratincola.* Since reclamation started, there has been a general decline of the population in the study area.

2. Collared pratincoles in the study area use marshland and farmland habitats for breeding with approximately half the population in each. However, marshland availability is only 3% of that of farmland. Colonies in farmland are found mostly in cotton fields.

3. Collared pratincoles chose marshland to breed. Here low vegetation cover and dry soil are important for settlement. In farmland, low vegetation cover, dry soil and flat terrain are important factors. Changes in crops affect pratincole colony location from year to year, but they tend to stay in the same areas.

4. Nest-site selection is not determined by the proximity of tussocks or the height of these. Hoof prints or cow-dung are not selected as nest sites, most of the nests being laid on scrapes on dry mud. In farmland, more nests are laid on plant rows than between them. This is important for their survival when work in the field takes place.

5. Colonies in marshland and farmland were of similar size and held similar number of pratincoles. Clutch size and mean clutch weight did not differ between the main study colonies (marshland and farmland), but mean clutch volume did. Eggs were bigger in the marshland colony. No difference between years was found for any of these variables.

6. Pratincoles feed mainly on insects captured in the air. They mainly use marshes and reeds for feeding. Food availability in these is higher than in crops. Crops, except cereals, are hardly used for feeding. Food availability in crops (non cereals) was also lower.

7. During the chick-rearing period adults tend to feed in the colony or nearby. Before and after this period, they often move to areas of marshes and reeds where they feed in groups.

8. Daily activity is highly influenced by insect activity and, therefore, by the weather conditions. Pratincole feeding density decreases on rainy, windy and cloudy days. In general, their activity increases through the morning up to early afternoon, and decreases after that. At certain places, activity at dawn and dusk has also been recorded.

9. Food availability in different habitats in the study area was studied with pit-fall and sticky-traps. The most trapped taxa were Coleoptera and Hemiptera. These were also the most represented taxa in chick faeces.

10. Predation of eggs in the study colonies in both types of habitat was negligible. Most clutch losses in marshland were due to abandonment and in farmland to the effect of machinery working in the field. Altogether, hatching success was high in marshland (73%-91%) and low in farmland (12%-35%). It was not possible to measure fledging success due to the difficulty in locating chicks after hatching. Different methods were tried without success.

11. This study presents data only on first clutches as it was not possible to locate replacement ones. Therefore, it is not known to what extent these make up for the loss of pratincoles first clutches. However, it is unlikely that hatching success in replacement clutches will be any higher than for the first ones since agricultural activity tends to increase rather than decrease as the season progresses.

12. Breeding performance in marshland and farmland was consistent between years within the same habitat except in farmland in 1993 when, because of an exceptional lack of water much of the farmland was not cultivated or crops were left abandoned. This allowed pratincoles to achieve a higher hatching success than in normal years in this habitat.

13. Different hypotheses to explain why pratincoles keep breeding in farmland (lower breeding performance) are discussed. Lack of marshland habitat and colony-site fidelity may have an influence on this.

14. Chicks from marshland and farmland colonies in the Guadalquivir marshes area were growing similarly. There were no differences between habitat or years. Chicks were being fed the same number of times and their diet was similar. Adult attendance did not differ either. Food does not seem to be a constraint on chick production.

15. Management rules for pratincole colonies in marshland and farmland are proposed. In marshland, control on cattle grazing, vegetation cover and level of water would improve marshland conditions for the birds. In farmland, coordination of the timing of works on crops with pratincole breeding times would improve their breeding success. Conservation of areas with reeds and shallow waters are very important as pratincoles feeding habitats. The same is the case for marshes, which are also important as breeding places.

16. The pratincole population in the area is some 80-85% of the Spanish population. This, in turn, is the most important breeding population in Europe (40%-50%). Considering

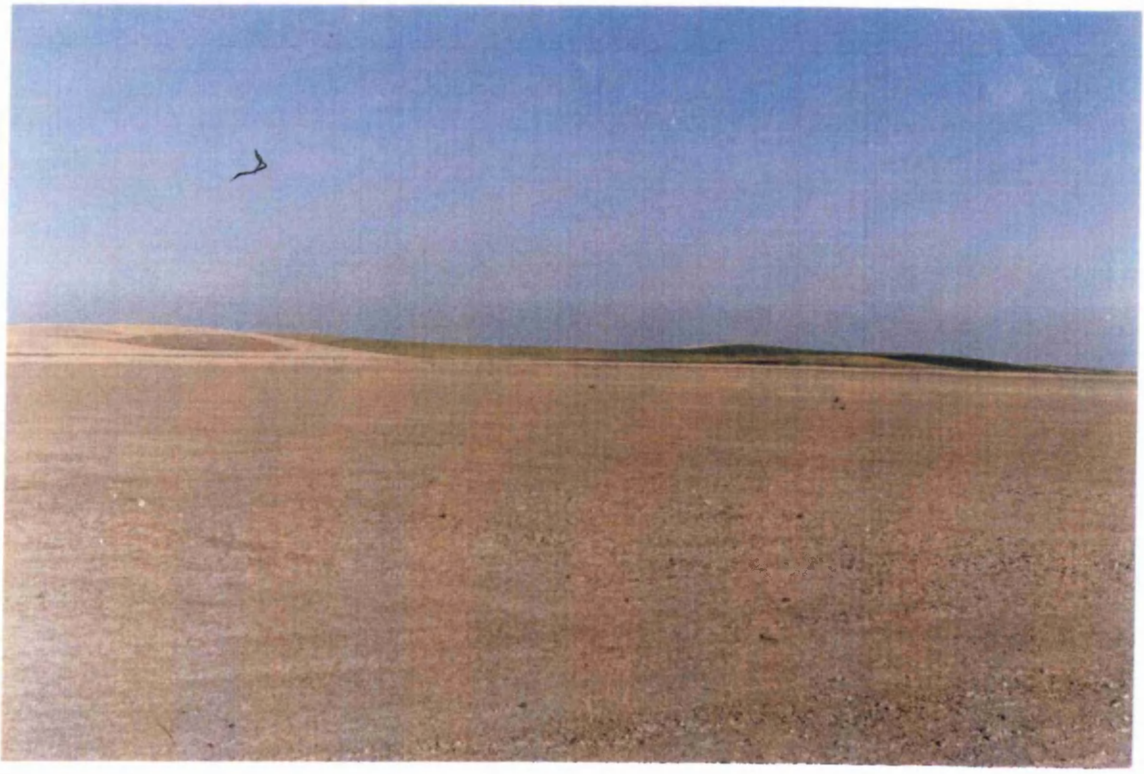
that most of the pairs nest in reclaimed land, measures to protect this species would be desirable. Otherwise the population will probably continue to decline.

Collared pratincole *Glareola pratincola*.

Collared pratincole colony in a cotton field.

Collared pratincole colony in a sunflower field.

Collared pratincole colony in marshland habitat.



Collared pratincole colony in fallow land.

Collared pratincole nest with no added material.

Collared pratincole nest with added material.

Collared pratincole chicks.

Tractor raking between rows in a colony located in a cotton field.

Implement used in cotton fields in very dry years.

CHAPTER 1

GENERAL INTRODUCTION

1. MARSHLAND RECLAMATION FOR AGRICULTURE AND OTHER PURPOSES

Many waders (Aves: Sub-order *Charadrii*) depend on wetlands for breeding, wintering and as stop-overs during migration (Hale 1980). Wetlands have suffered great degradation world-wide (Dijkema 1984, Erwin *et al.* 1986, Williams 1990a, Finlayson & Moser 1991, Hunter *et al.* 1991, Whigham *et al.* 1993), lands being drained and used for urbanization, for industrial, recreational and agricultural purposes (Williams 1990b). These changes have occurred in coastal and inland wetlands (Evans 1991, Finlayson & Moser 1991), affecting birds in different ways depending on the use they made of that particular land: as a wintering place (e.g. Lambeck 1991), migration stop-over (Evans *et al.* 1991) or breeding ground (e.g. Kohler & Rauer 1991). Several wader species also use natural grasslands for breeding, and these have also been widely degraded and transformed (Fuller 1987, Ledant 1989, Beintema 1991, Davidson 1991). In spite of these changes in natural breeding habitats, many wader species continue breeding in the traditional areas now transformed into agricultural land (Beintema 1986, Calvo & Alberto 1990). In many cases, numbers of breeding birds have decreased (O'Connor & Shrubb 1986, Baines 1988, Machikunas 1989, Hötker 1991, Berg 1992, Thompson & Coulson 1992, Calvo *et al.* 1993) or nearly disappeared (Baines 1988, Witt 1991) from their original breeding grounds. Declines are not universal however. Oystercatchers *Haematopus ostralegus* have started breeding in grassland in areas not used before (Baines 1988).

Meadow transformations in the Netherlands were positive for waders in the first stage. Fields were kept wet during the breeding period, preventing cattle and machinery entering too soon into the fields and keeping good feeding conditions for wader chicks (Beintema 1981). Modernization and more intensive agricultural activity are affecting birds breeding on farmland. Breeding success can be lowered due to cattle trampling, machinery working on the fields or an increase in predation (Beintema & Muskens 1987, Kooiker 1987, Galbraith 1988a, Baines 1990, Shrubb 1990, Westphal & Mansard 1990, Baines *et al.* 1991, Jönsson 1991, Berg 1992). Timing of farming practices, type of crop and crop growth can also determine breeding success (Galbraith 1988a, Berg 1992). In most of these cases productivity is too low to maintain the population. The reasons why birds keep breeding on farmland are not known for most of the species. Galbraith (1988a) suggested that lapwings *Vanellus vanellus* using arable land (low productivity) had short-term benefits (good feeding conditions), although this could not explain why they kept breeding there. Thompson & Coulson (1992) found that this species is highly philopatric and shows a high degree of breeding site-fidelity. Witt (1991) said that farmland can show features which also exist in natural habitats and will be chosen by birds even when it is not a suitable place for breeding. He considers these areas as traps as they "induce ineffective breeding".

As in many other countries, land-policy in Spain has been that of draining and transforming wetlands into industrial or agricultural lands. One of the best documented cases is that of the Guadalquivir marshes. These were hardly influenced by humans until this century, although a few attempts to transform them were made before (Menanteau 1984, Reguera 1983, Cruz 1988). Two main actions have transformed the marshes in recent decades: changes in the river Guadalquivir channel to allow navigation up to Seville, and drainage of marshes for agricultural use. The former has altered the natural hydrological process of the marshes and the latter has destroyed most of the marshland surface (minimum of 70%, Sánchez *et al.* 1977). Reguera (1983), Menanteau (1984) and Cruz (1988) describe the process of drying-up. The last two authors also evaluate the land policy carried out in the area and discuss the consequences of it.

The marshes of the Guadalquivir river have long been famous for their rich fauna (Lilford 1865, Saunders 1869, Irby 1895, Witherby 1899, Chapman & Buck 1893, 1910, Verner 1909, Yeates 1946, Robertson 1954, Mountfort 1958, Valverde 1958, 1960, Mountfort & Ferguson-Lees 1961). At present there is an area of marshes included in the National Park of Doñana and some marsh "islands" patchily distributed within agricultural land outside the park. There has obviously been a big impact on the fauna, although data previous to the transformations are scarce and comparisons cannot easily be made. The species and numbers of birds using the reclaimed lands for feeding, roosting and breeding have changed, leading to the disappearance of some species from the area and to the expansion of some others (Barrera *et al.* 1984). Part of the channels, river arms and side banks outside the National Park have recently been protected by law (Ley de Espacios Naturales Protegidos, 2/89 de 18 de julio). The situation in the inland wetlands of the province of Seville (see Chapter 2 for study area description) has been very similar and most of them have been dried up, reduced or transformed into fields (Senra 1984). Threats that wetlands in the province of Seville face are described in Senra (1984) and Vélez (1984).

The importance of this wetland net in south-western Spain as a stop-over for migrating birds and as a wintering or breeding place for others is well known (Valverde 1958, 1960, ICONA *in press*). Nevertheless, there are no detailed studies evaluating the effects of changes in the area on the avifauna. To carry out such a study I chose a species, the Collared pratincole *Glareola pratincola*, which has traditionally bred in high numbers in the Guadalquivir marshes and inland wetlands of the province of Seville, and which at present breeds in natural marshland as well as in fields located where there used to be marshes. Pratincoles are well adapted to conditions in the marshes, they depend on water for food production (they feed on insects) and on the marshes drying up in spring time to provide nesting ground. Numbers of colonies and individuals in the study area (see Chapter 3) were considered adequate to carry out the study.

2. COLLARED PRATINCOLES

Collared pratincoles belong to the Family *Glareolidae* (Sub-order *Charadrii*, Order *Charadriiformes*) which includes two sub-families: coursers (*Cursoriinae*) and pratincoles (*Glareolinae*). This Family has been said to have affinities with Families such as *Burhinidae*, *Charadriidae* and *Laridae* (for summary see Hale 1980, Cramp & Simmons 1983). Sibley &

Monroe (1988) suggested that the Family *Laridae* was the closest to *Glareolidae* on the basis of their DNA hybridization analyses.

The Family *Glareolidae* is mostly distributed in the Ethiopian and Oriental regions with a few species in the South Palearctic and Australasian regions. Although there are no species in the New World at present, fossils of a species (*Paractiornis perpusillus*) closely related to the genus *Glareola* were found in Nebraska (Olson & Steadman 1979, Olson 1985). Coursers are long-legged, terrestrial species, adapted to dry conditions. They tend to nest sparsely, not forming colonies. As with most of the members of the Family *Glareolidae*, they have cryptic plumage and feed largely on insects. On the other hand, pratincoles are short-legged and more adapted to flying. They obtain food mainly in the air and tend to nest colonially (Hale 1980, Campbell & Lack 1985).

The sub-family *Glareolinae* includes eight species (Hayman *et al.* 1989, Howard & Moore 1991) of which seven belong to the genus *Glareola* and one to the genus *Stiltia* (Table 1.1). *Stiltia* has structural and behavioural characteristics from both sub-families (Maclean 1973, 1976) and there are suggestions that it should be placed in a separate sub-family (Condon 1975). *Glareola pratincola*, *Glareola nordmanni* and *Glareola maldivarum* have sometimes been considered as races of the same species although most authors treat them separately on the basis of differences in structure, colour and voice (Hayman 1956, Szábo 1973/4, Sterbetz 1974, Glutz *et al.* 1977, Cramp & Simmons 1983, Mauersberger 1990) and of geographical and habitat separation (Szábo 1973/4). *Glareola pratincola* and *Glareola nordmanni* have been recorded breeding in mixed pairs (Wamsley 1970, Szábo 1973/4). The hybrid off-spring are viable but nothing is known about their fertility.

There are generally recognised to be five sub-species of collared pratincole (Table 1.2, Dementiev & Gladkov 1969, Howard & Moore 1991). Nevertheless there are authors who question *G.p.limbata* as a sub-species (Sterbetz 1974, Cramp & Simmons 1983) and consider the possibility of these birds belonging to either G.*p.pratincola* or to *G.p.fuelleborni*. The study taxon in this thesis is the nominate *G.p.pratincola*, the only one of the sub-species found breeding in Europe. For convenience it will be referred to as collared pratincole or just pratincole from now on. Wintering quarters are not well delimited but they are mainly in Africa, south of the Sahara. A small part of the population winter in Asia. From the end of March to May they arrive on the breeding grounds in north Africa, southern Europe (Fig. 1.1) and west Asia. Migration to winter quarters goes on from July to October (Cramp & Simmons 1983).

Table 1.1 - Species included in the sub-family *Glareolinae* after Hayman *et al* (1989) and Howard & Moore (1991).

SPECIES	WORLD DISTRIBUTION
Glareola pratincola Linné 1766	S Palearctic, Ethiopian, Oriental
Glareola maldivarum Forster 1795	Oriental , S Palearctic
Glareola nordmanni Fischer 1842	S Palearctic
Glareola ocularis Verreaux 1833	Ethiopian
Glareola nuchalis Gray 1840	Ethiopian
Glareola cinerea Fraser 1843	Ethiopian
Glareola lactea Temminck 1820	Oriental
Stiltia isabella Vieillot 1826	Australasian

Table 1.2 - *Glareola pratincola* sub-species. After Dementiev & Gladkov (1951) and Howard & Moore (1991).

SUB-SPECIES	DISTRIBUTION
G.p.pratincola Linné 1766	Mediterranean to NW India & Africa
G.p.boweni Bannerman 1930	Senegal to Chad and Gabon
G.p.limbata Rüppell 1845	Sudan, Ethiopia, Somalia and S Arabia
G.p.erlangeri Neuman 1920	Coastal areas in S Somalia and N Kenya
G.p.fuelleborni Neuman 1910	E Zaire, C Kenya to Cape Province

There has been hardly any information on the size of the European breeding population of collared pratincoles until quite recently. In 1986 the population was guessed to be 550 to 1350 pairs (Piersma 1986) although there were no data available for many of the breeding sites. Uhlig (1989) reviewed data on population and status of the collared pratincole in eastern Europe, and Nadler (1990) reviewed the records of the species in central and northern Europe. In 1989 a national census was carried out in Spain, obtaining a total of 3761-3815 pairs (Martínez 1991), most of them - 80%-85% - in the province of Seville (Calvo 1993, Calvo *et al.* 1993). The species is also included in the project "Atlas of Colonial Waterbirds breeding in the Mediterranean region 1994-1995". With these figures a more thorough knowledge of the European and African breeding population will be obtained. From the information available up to now, the study area in the province of Seville holds a very important part (40% to 50%, based on estimates of maximum and minimum breeding population size, respectively) of the whole European population (Table 1.3).

Table-1.3 - Estimates of breeding populations of collared pratincoles in Europe during the 1980s.

COUNTRY	MINIMUM-MAXIMUM	SOURCE
Albania	100- 300	Lamani 1993
Bulgaria	25- 50	Iankov 1993 *
France	22- 22	Cramp & Simmons 1983
Greece	500-1000	Carsadorakis 1993 **
Hungary	30- 120	Waliczky 1993***
Italy	30- 90	Tinarelli & Bacetti 1989
Portugal	100-1000	Rufino 1989
Romania	100- 100	Uhlig 1989
Spain		
Seville province	2500-3000	Calvo 1993
All other areas	1261-1315	Martínez 1991
Ukraine	280- 420	Uhlig 1989
Yugoslavia	40- 150	Bartovsky *et al.* 1987
Total	4988-7567	

* Citing Michev *et al* (1990).

** Citing Goutner (1983), Joensen & Jerrentrup (1988) and Pergantis (1986).

*** Citing Konyhás & Kovács (1990).

Although complete population counts do not exist to allow the trend in population size to be established, there are census data over periods of years in certain areas. From counts in different breeding areas it can be inferred that the trend in number of breeding pairs is in general a decrease (Sterbetz 1974, Uhlig 1989, 1990, Calvo *et al.* 1993). Nadler (1990) found that the number of records in central and northern Europe had increased since 1950, but he attributed this to more intense ornithological observation. Different reasons, all related with land-use and agricultural activities, have been proposed for the decrease; such as loss of habitat, reduced food availability due to the use of chemical products or reduction in the number of cattle and so less insects (Sterbetz 1974, Martínez 1985, Uhlig 1989, Nadler 1990). Collared pratincoles are considered vulnerable in Spain (Blanco & González 1992) and the species is included in Annexe 1 of the Birds Directive 79/409/EC.

As said above, most of the surface of the marshes of the Guadalquivir river and land adjacent to wetlands further inland has been reclaimed for agriculture. This study determines how this land-use policy and the present land-use and agricultural practices affect collared pratincoles, a species which has traditionally nested on marshland. In Chapter 2 the study area and general methods are described . In Chapter 3 information on the breeding biology of the species in the study area is presented. The next three chapters deal with the effects on habitat selection (Chapter 4, see also Appendix 2), food availability and feeding activity (Chapter 5) and reproductive success (Chapter 6). In the last chapter, in which conclusions from all previous chapters are gathered, some management rules are suggested. I wished to avoid using any research methods that might have adverse effects on the survival or breeding success of the study birds, especially because collared pratincoles are scarce and decreasing. In order to evaluate possible effects of using any form of marks or devices on study birds I reviewed the literature on this subject (Appendix 1). Information on the numbers of pratincoles breeding in southwest Spain is given in Appendix 2.

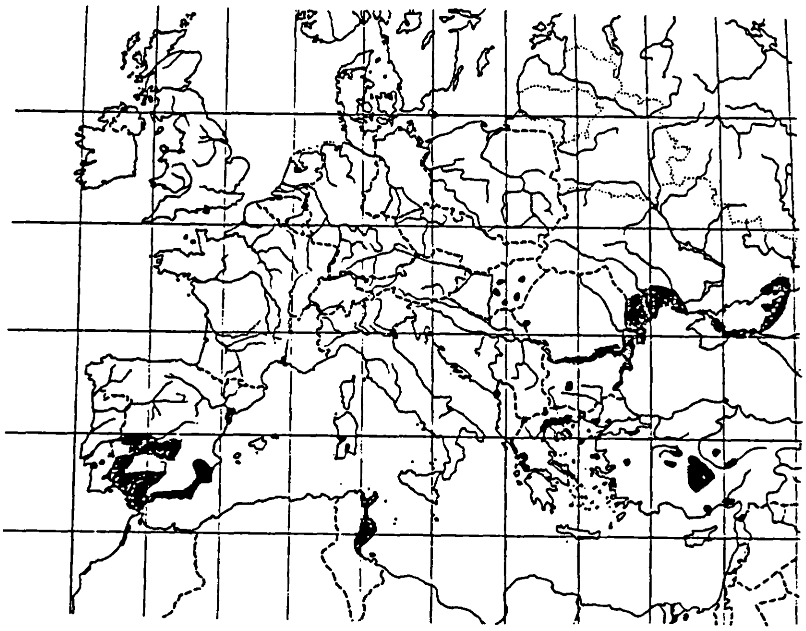


Figure 1.1 Pratincole breeding range in Europe and North Africa.

CHAPTER 2

STUDY AREA AND GENERAL METHODS

1. STUDY AREA

The study area is located in the province of Seville, southwest Spain. Three regions within the province (792729 ha.), in which nearly all the flat areas are included, have been considered (Fig. 2.1). It is basically a depression through which runs the river Guadalquivir (Fig. 2.2). For a detailed description of the topography, climate, soil and vegetation in the area see Drain *et al.* (1971), Grande (1973) and Cano (1987). Part of the marshes of the Guadalquivir river, most of them reclaimed for agriculture, are within the limits of the study area. The National Park of Doñana is not included, although some data on food availability and some observations have been carried out there and results are presented in this thesis. Two different habitats will be considered: farmland and marshland.

1.1 Farmland

There is a wide range of crops in the study area (Table 2.1). Olive trees and intensive farming of herbaceous plants (cotton *Gossypium* spp., sunflower *Helianthus annuus,* beetroot *Beta vulgaris*, cereals, chickpeas *Cicer arietinum*) are the most important crops. Although small changes in the number of hectares may occur from year to year, the same pattern is kept throughout the years. Most of the crops are grown in spring and summer time. Due to the dry weather conditions in the area in the summer, irrigation is widely used.

Of all crops, only part of the herbaceous and rice *Oryza* spp. fields are, in principle, potentially available for pratincoles to settle in as they look for flat, or slightly elevated, open areas with little or no vegetation cover (Calvo & Alberto 1990). Which crops allow settlement is discussed in Chapter 4.

1.2 Marshland

All marshlands left in the study area are fragments within agricultural land, most of them in the Guadalquivir river marshes and a few associated with inland wetlands. The former are

Table 2.1 - Hectares of crops in the study regions. Data from the Consejería de Agricultura y Pesca, Junta de Andalucía, 1988.
* = Potentially available crops for pratincoles to settle.

Crop	Has.	
Fruit trees	14124	
Olive trees	71934	
Vineyards	2080	
Olive trees/Vineyards	43	
Market gardens	2005	
Greenhouses	206	
Rice	32000	*
Herbaceous	491697	*
Intensive farm-work, trees	385	
Extensive farm-work, trees	1288	

mainly fragments running by channels and irrigation ditches. The latter are usually basins of lagoons that have been dried out but are not sown.

Vegetation is formed by halophyte plants, mainly *Sarcocornia perennis perennis*, *Suaeda splendens*, *Suaeda vera*, *Frankenia laevis*, *Spergularia* sp., *Plantago coronopus*, *Polygonon maritimum*, *Polygonon monspesulanum*, *Atriplex chenopoides*, and *Hordeum marinum* (after Valdés *et al.* 1987). In some places meadow vegetation grows together with marsh vegetation.

When first reclaimed, it takes several years to get a good crop from marshland due to the high salinity of the soil (Grande 1973). During the first years of reclamation soils are drained and washed but not sown. Marsh vegetation is removed but in these first stages it develops again and is successively removed. First crops used are usually barley *Hordeum* spp. and oats *Avena* spp. (Anon. 1986).

Marsh fragments are frequently used for cattle, sheep and horse grazing. In June most of these animals are removed as there is hardly any food left for them. From June on and throughout the summer many marsh fragments are used to set beehives.

1.3 Weather

Weather data were obtained from Los Palacios weather centre, the closest weather station to the highest number of pratincole colonies. The area is characterised by mild winters and long hot dry summers. Rainfall occurs mainly in winter and spring time with hardly any rainfall during the summer months. Rainfall in the winter 89/90 was higher than average and water condition in springtime 1990 was better than in any other year. 1992 was drier than previous years and the dry conditions remained through 1993. Some stormy showers occurred during April and May 1993 (Fig. 2.3).

2. FIELD WORK TIMING AND GENERAL METHODS

Field work was carried out in 1989, 1990 and 1992. There was no previous information on colony location or habitat use by collared pratincoles in the area. In 1988 the province of Seville was travelled mapping colonies and recording habitat use. Then, the study area was delimited. In 1993 a short two-week field season was undertaken to obtain further measurements from chicks in different habitats.

Specific methods concerning each chapter will be described where appropriate. In this chapter only methods for colony and nest location and for chick and adult capturing and marking will be described.

2.1 Colony location

Colonies were located by driving through the open fields in the study area. Lowlands and farmlands near water such as marshlands, channels, streams, lagoons and temporary pools were searched intensively. A study of wetland loss in the province of Seville since 1918 was carried out. This study was of great help in locating farmlands which had previously been wetlands, and which were often occupied by breeding colonies.

2.2 Nest location and marking

Nests were located by systematically searching in the colonies. Searches were carried out by three persons at one time, early in the morning. Two hours after sun rise, searches were stopped to avoid subjecting nests to excessive insolation. All plots of land containing colonies had a rectangular shape which helped allow thorough searching and allowed the birds in zones that were not being searched to go back to their nests, which they readily did when we were more than 150 m away. Searches were carried out in mid-May, when the laying peak had passed. It took four search days to cover all the colony in each year. Nests were marked with a wooden stake placed four meters away from the nest, always in the same direction.

Many authors have reported problems associated with searching for and marking nests, warning of the negative effects that these procedures can have (Duffy 1979, McInnes 1980, Rodgers & Burger 1981). Observer induced predation and thus, a decreased hatching and/or fledging success has been reported many times (Kury & Gochfeld 1975, Robert & Ralph 1975, Bart 1978, Strang 1980, Safina & Burger 1983, Salathé 1987, Strauss & Dane 1989). Most authors attribute this to the ability of predators to follow the person by scent or sight. A high number of visits (Major 1990) as well as the type of nest marks used (Hammon &

Forward 1956, Picozzi 1975, Bowen *et al.* 1976) can also increase predation. Nevertheless, in a study of a related bird with similar nesting habits to the pratincole, Galbraith (1987) did not find any difference in the probability of nest predation between marked and unmarked lapwing nests and amongst nests checked from a car, nest approached and eggs not handled, and nests approached and eggs handled.

Observer disturbance can cause a decrease in breeding success (Westmoreland & Best 1985, Pierce & Simons 1986, Piatt *et al.* 1990) for reasons other than predation such as nest abandonment (Ellison & Cleary 1978, Livezey 1980), chicks dying of exposure, starvation or aggression or possible cannibalism from conspecific neighbours (Gochfeld 1981), or a change in adult behaviour (Fetterof 1983).

I believe my method had no negative effects on breeding success. In the marshland colony, 4 out of 52 (7.7%) clutches were lost: 2 being abandoned and the other 2 taken by predators. Searches were carried out on 12, 13 and 15 May. Short checking visits were carried out every third day approximately thereafter. No nest losses occurred in the three days immediately after nests had been located, the four clutch losses occurring around 20 May and 30 May. Losses in the farmland colony also occurred predominantly many days after nest-marking.

2.3 Chick capturing and marking

Pratincole chicks abandon the nest a few hours after hatching. Locating chicks afterwards is difficult due to their crypticity and the high mobility of broods. Chicks were captured by two persons, one spotting them from outside the colony and keeping the chick under observation and the other following directions to the chick. Dazzling them at night with a torch was also tried. The method was successful and even fledged chicks could be captured. All chicks were ringed with metal individually numbered rings.

2.4 Adult capturing

Adult capturing and marking was planned for purposes such as studying bird movements within the area, degree of philopatry or fledging success (by locating broods through adults). Different marking methods were considered. Previously, a review of the effects of different marks was carried out (see Appendix 1). Very few pratincoles are ringed per year and those ringed are usually chicks. This is due to the difficulty of capturing adults which very seldom are caught in any of the conventional trapping methods such as mist-nets. Capturing them out of the colonies is not easy as they feed too high for mist-nets. Different methods inside the colony were tried. It has to be kept in mind that due to the high temperatures reached in the area, any trapping method has to be fast. Even if the hot peak hours are avoided, traps should not be left long in the colonies. The following methods were tried:

1. Clap-nets with bait. Traps were placed in a colony. Pratincoles did not approach them.
2. Dazzling birds with torch at night. It was tried on dark calm nights. Birds flew when approached to within 5 to 10 m.
3. Heart-shape walk-in trap. Birds did not walk into the trap.
4. Drop-cage trap. This was only accepted after a long time and was not efficient as the terrain is not uniform and birds can escape through small gaps.
5. Loops around the nest. A rectangular mesh densely covered with catgut loops was placed around the nest. Loops covered all the mesh surface. Birds accepted it readily but walked in and out without entangling.
6. Sponges soaked in dye. Dying adult breast feathers by placing sponges soaked in picric on the nest cup was also tried. The birds accepted the cotton wool straight away but the method proved inefficient as feathers did not absorb the dye. Presumably the dye had dried out too quickly under the hot conditions.
7. Clap-nets over the nest. Four adults were captured this way. Three of them abandoned their clutches and the partner did not resume incubation either. The fourth managed to escape from the net and incubation was resumed immediately we had left the colony.

The eggs hatched successfully. It seems therefore that the handling procedure stressed the birds. They were not seen again in the area and capturing adults was abandoned.

This difficulty in capturing and marking birds leaves certain important questions unresolved, although some indirect approaches have been tried.

2.5 Statistical procedures

Before any other statistical procedures, data were initially tested for normality using Kormogorov-Smirnov one sample tests. Proportions and percentages were converted with the arcsine transformation. Non-normally distributed data were transformed. If still not normally distributed they were analysed using non-parametric techniques. Normally distributed data were analysed with parametric tests. Where required equality of variances of the sub-samples was tested using one-way ANOVA. To analyse data on habitat selection (Chapter 4) logistic regression analysis was used. In all tests the limit of significance was set at 0.05. Any values of p over 0.05 will be referred as to N.S. All analyses were carried out using SPSS-PC$^+$ programs.

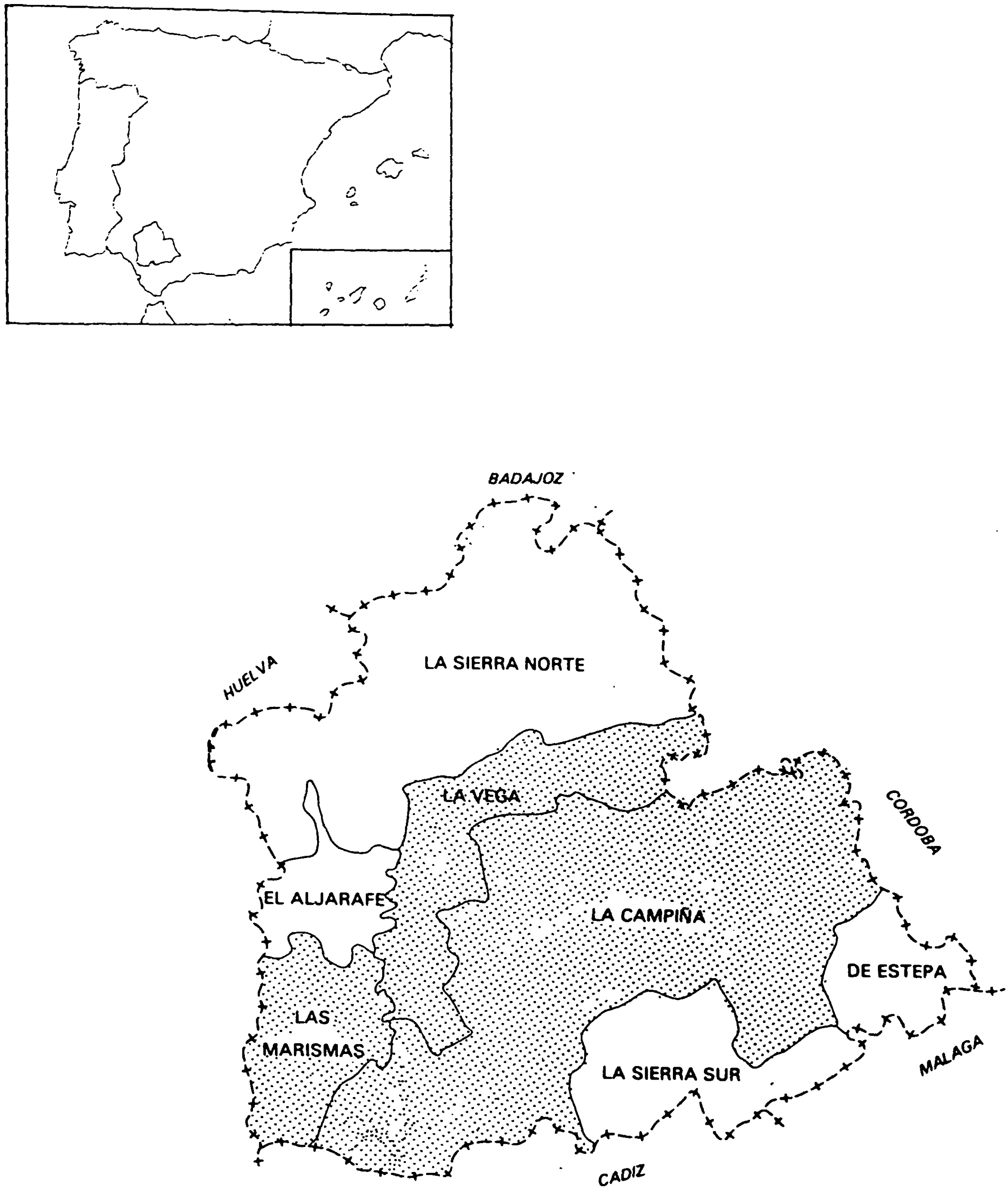


Figure 2.1 - Regions of Seville province included in the study area.

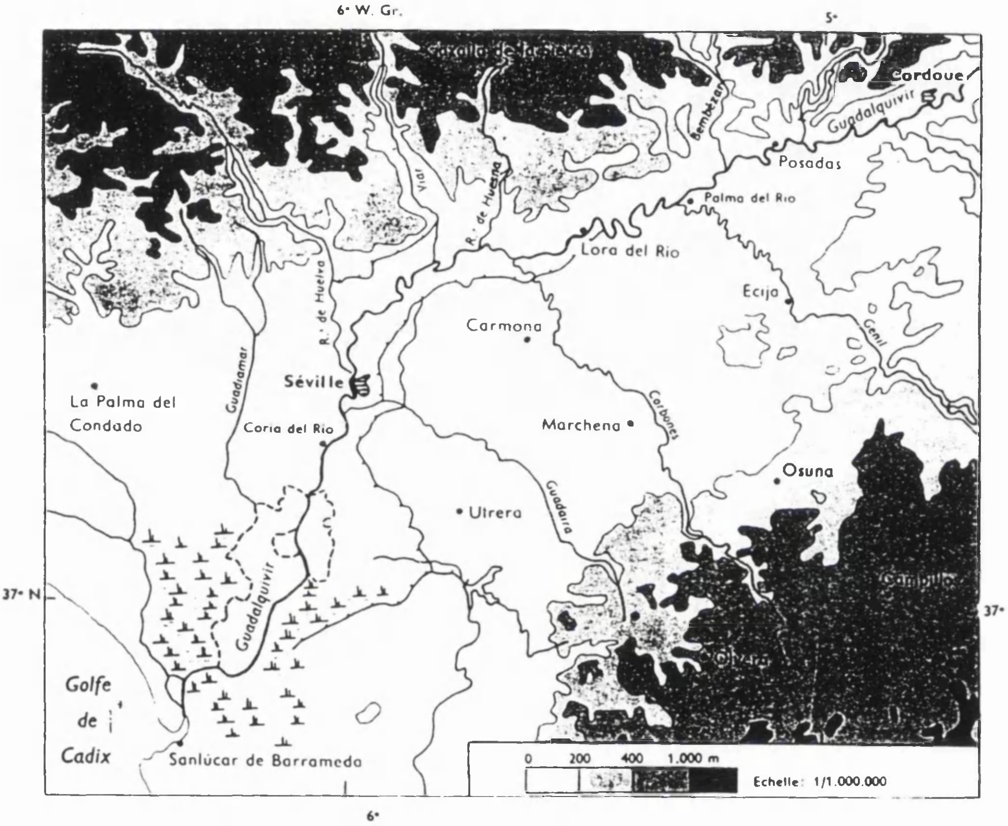
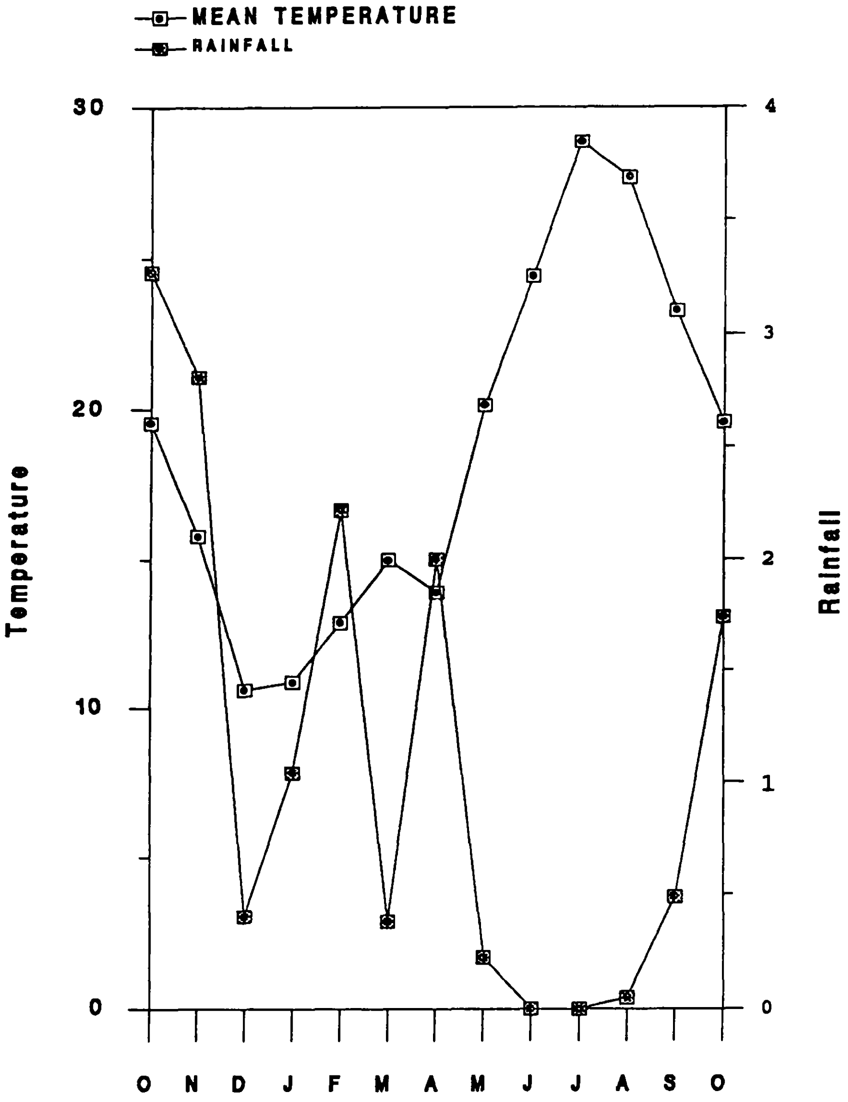


Figure 2.2 - Map showing elevation of central Seville province. The study area includes nearly all the flat areas in the province. After Drain *et al.* (1971).

Figure 2.3 - Mean temperature (ºC) and rainfall (mm/day) in the study area from 1988 to 1993.

1988/1989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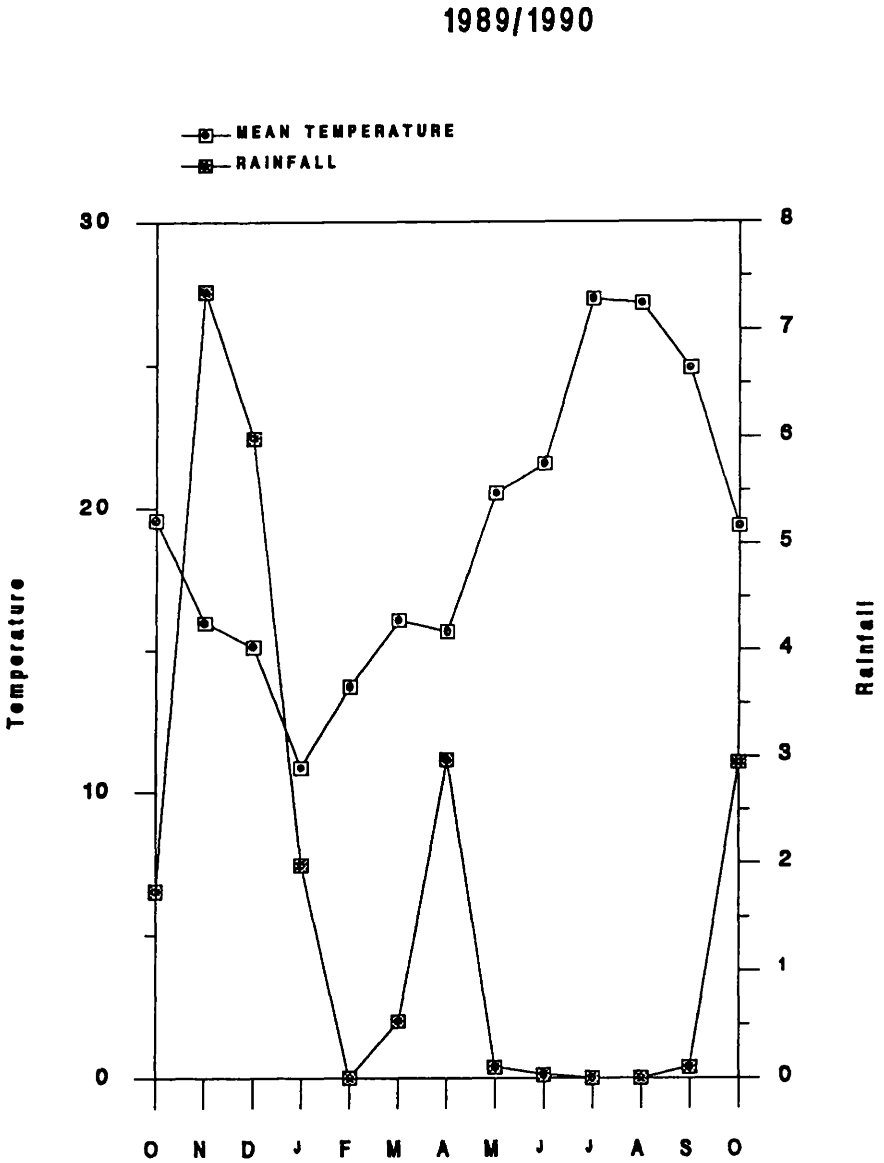
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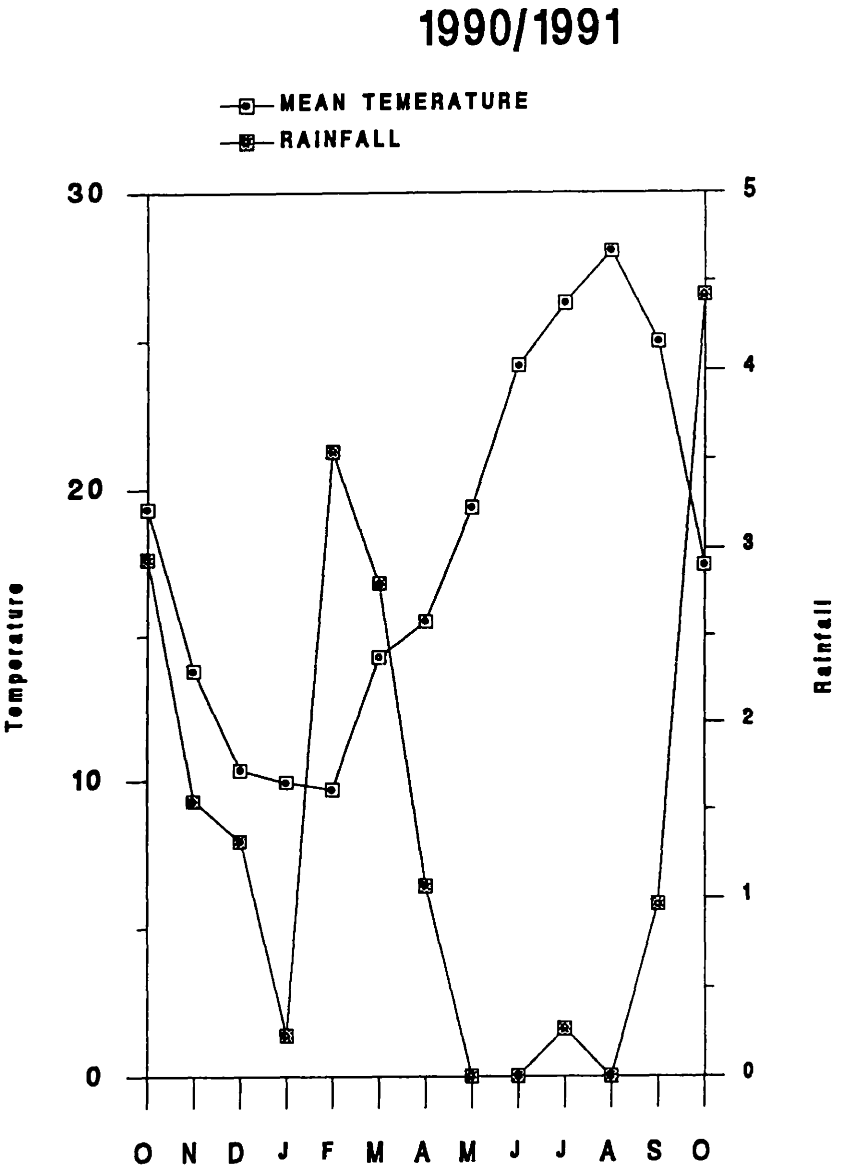
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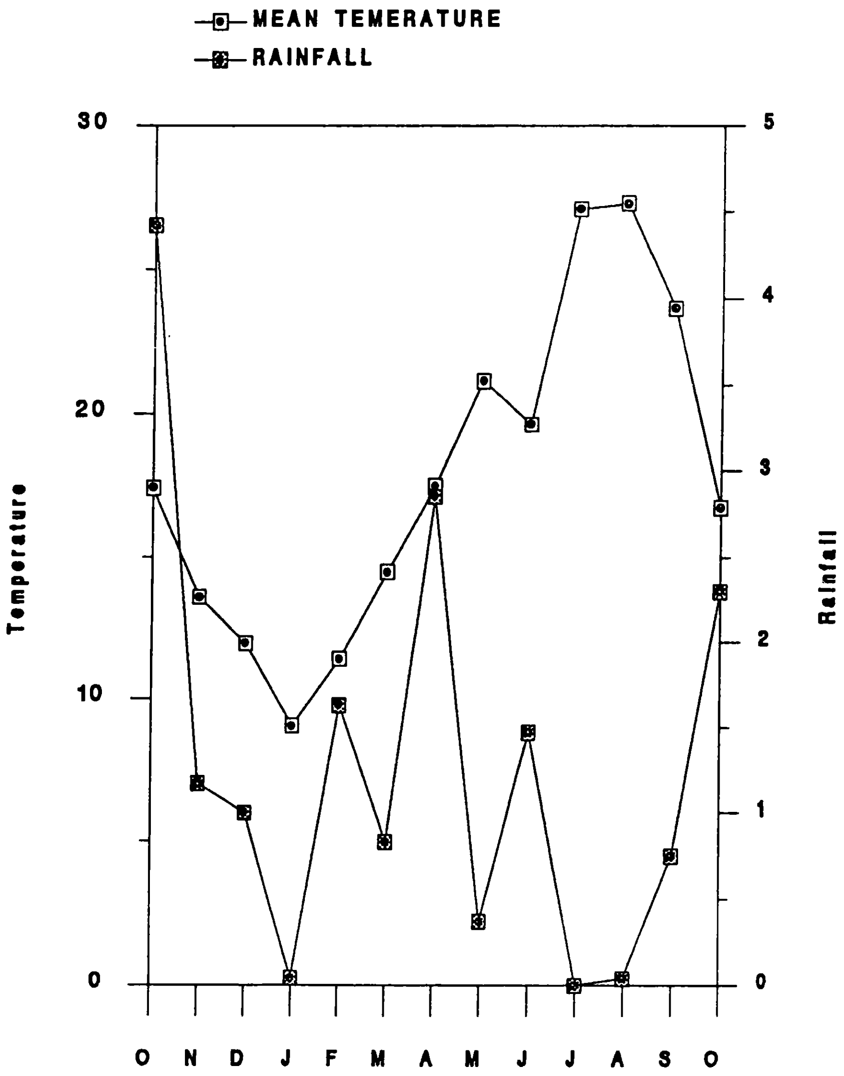

1991/1992

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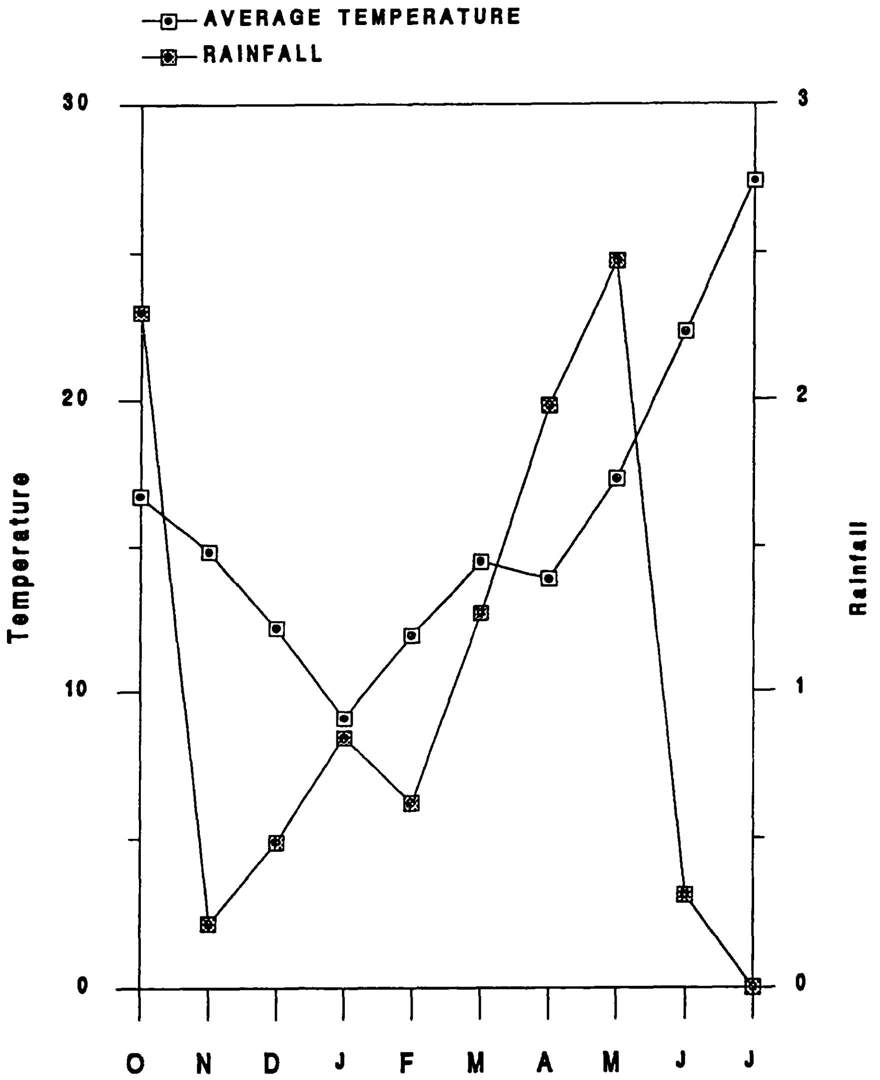
1992/1993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CHAPTER 3

PRATINCOLE BREEDING BIOLOGY

INTRODUCTION

Collared pratincoles nest in loose colonies in flat, or slightly undulating open areas. The sexes are alike and both take part in building the nest (a scrape on the ground), incubating the eggs (normal clutch size 2 or 3) and rearing the chicks. Although they have traditionally been considered monogamous (Cramp & Simmons 1983), it seems that co-operative breeding or polygamy can happen (Pozhidaeva & Molodan 1992). Walters (1982) found that in the southern lapwing, a species which "attended chicks actively" (measured as spatial relationships between adults and young and time devoted to tending behaviours by adults), three birds sometimes tended a single brood. This could be the case with pratincoles which also tend their chicks actively and, unlike lapwings, they have to pay the cost of feeding them until fledging. Studies on marked populations would be necessary to clarify this point.

Chicks fledge when about 30 days old. There are a few descriptions of chick development - not chick growth - in captivity (Cerva 1929, Müller 1948, von Frisch 1961), but not in the wild.

Altogether there are few studies on the breeding biology of collared pratincoles (Serle 1950, Valverde 1960, Pérez-Chiscano 1965, Dolz *et al.* 1989, Pozhidaeva & Molodan 1992) and most of the data available are records, counts, descriptions of behaviours or mere accounts of visits to colonies. Previous information on their breeding biology has been gathered in Sterbetz (1974), Glutz *et al.* (1977) and Cramp & Simmons (1983). In southwest Spain information on pratincoles was limited to basic records and partial counts, most of them within the limits of the National Park of Doñana. To carry out this study the first step was to locate the colonies and record the population and general habitat use in the area (Calvo & Alberto 1990, Calvo 1993, Calvo *et al.* 1993, Appendix 2). Then a study on the breeding biology was undertaken. The aim of this chapter is not to give a comprehensive study of their breeding biology, but to gather information which will allow interpretation of other aspects of pratincole ecology particularly in relation to land-use.

METHODS

1. COUNTS

Arrival, settlement in colonies and abandonment of the area was followed during 1989 and 1990. Dates and use of land were recorded for every period considered. Colonies were counted during the second half of May and first half of June, this being the best period to estimate number of birds present. Prior to this period there may be some nomadism of individuals and, after this period, there are juveniles that can be counted as adults.

Several difficulties were encountered when counting in the breeding colonies:

1. Counting from outside the colony underestimated the true number of individuals because birds could not all be seen on the ground. It was necessary to enter the colony in order to flush the birds.
2. In big colonies, only birds close to the intruder took off. It was necessary to have a second person to compare these counts with counts from outside the colony.
3. At certain times of the day and with certain atmospheric conditions, some individuals foraged away from the colony. Thus counts could under-estimate the real number of adults.

For this reason, the counts were carried out from sunrise to noon by two counters, with one of them walking through the colony.

2. STUDY COLONIES

The reproductive cycle was studied in two colonies in farmland and two colonies in marshland. All four colonies were located in a predominantly reclaimed area which used to be part of the marshes of the Guadalquivir river.

The main study colony in marshland was located in a 3.3 ha. fragment of marshland running between an artificial channel and a local road. Mean vegetation cover was 6.2% and mean height 15.6 cm. The most representative plant species were *Sarcocornia perennis perennis*, *Suaeda vera*, *Suaeda splendens*, *Hordeum marinum* and *Plantago coronopus*. Less abundant were *Frankenia laevis*, *Corex divisa*, *Ranunculus peltatus*, *Erodium* sp., *Chamaeleum fuscatum*, *Melilotus indica*, *Damasonium alisma*, *Anthemis cotula* and *Parapholis incurva* (after Valdés *et al.* 1987). Cattle grazed in the marsh until the end of May. Hatching success was also recorded in a smaller colony of the same characteristics.

The main study colony in farmland was in a 3.7 ha cotton field, in reclaimed marshland. By the time of settlement no plant growth had occurred, so it had the appearance of ploughed fallow land. Cotton plants were approximately 9 cm high on 15 May, 40 cm on 9 June and 60 cm on 5 July. Distance between lines of plants was 95 cm. A second colony of similar characteristics as the one described above was also studied. In the second colony only 30% of the nests were followed. When referring to the "marshland or farmland colony" or "marshland or farmland 1" in the text I mean the main study colonies in each habitat.

3. COLONIES

3.1 Colony area and density

When counting a colony its extent was estimated. An approximate area was calculated in the field if the colony could easily be approximated to a regular shape. If not, its shape was drawn on a 1:50000 map and then the area calculated from it with the aid of graph paper. With these data a rough density measure was calculated for each colony in 1990, as for this year data on colony area were consistently taken by the same persons.

3.2 Colony vegetation cover

The general method for measuring vegetation cover in colonies is described in Chapter 4. For the marshland colony a more detailed record of vegetation cover and height was carried out to assess their effect on reproductive parameters. In this colony grass vegetation was very low, scarce and with a cover of less than 1% at the time of settlement. For this reason only tussock cover was considered. Four transects along the long axis and 20 across the short axis (at right angles to the long transect) were made using a 50 meters tape measure.

4. NESTS

4.1 Nest structure

Most collared pratincole nests are simple scrapes on the ground. Some of them have a noticeable amount of pebbles, little stems or small lumps of mud. Nests were assigned to one of the two categories: scrape or scrape with materials.

4.2 Nest dispersion

To study nest distribution the two main study colonies were divided into plots. The marshland colony was divided into 6 plots of 157 × 30 meters approximately each and the farmland colony into 8 plots of 41 × 114 meters each. The ratio of the variance to the mean number of nests multiplied by the degree of freedom was used to determine departure from random (Fowler & Cohen 1990).

$$X^2 = (S^2/(\text{mean})) \times (n-1)$$

4.3 Nest spacing

Distance from each nest to the nearest three conspecific nests was measured in the colony in marshland and the colony in farmland. The mean of the three measurements was used as the value for nest spacing. Subsequent observations indicated that about 95% of the nests in each colony had been found and marked. For the marshland colony also the distance to the nearest three stilt *Himantopus himantopus* nests was recorded.

5. EGGS

Data in this section are from the main study colonies.

5.1 Clutch size and egg measurements

Clutch size was recorded for all nests. Only those which were certainly known to be a complete clutch were used (assessed from egg density, see below). For analysis clutch sizes were grouped into small (1 or 2 eggs) or big (3 eggs). The mean clutch volume and weight were used for comparisons. The two 5 egg clutches were not included in the analyses concerning clutch size as the eggs could have been laid by two different females.

Egg length and breadth were measured with a calliper to the nearest 0.1 mm. Weight was obtained with a Pesola spring balance to the nearest gram. Not all egg measurements were taken for some of the clutches. This happened especially in the farmland colony where my work could interfere with the farmers' activities.

5.2 Egg volume

Calculation of egg volume has been a concern to many scientists due to the difficulty of measuring it accurately in the field. Different suggestions have been made, but the one based on the egg linear dimensions has been widely accepted (Coulson 1963, Stonehouse 1963, 1966, Hoyt 1979) and is the one that will be used in this study. Volume (V) was calculated with the formula $V = Kv \times L \times B^2$, where L is egg length, B is egg breadth and Kv is a constant which differs between species. Five fresh eggs from different clutches were used to calculate the constant Kv for collared pratincole eggs. These were pierced at both ends and emptied by blowing the contents. Once the inside was clean, the internal volume was calculated by filling the eggs with water. A precision balance (0.001 g) was used to weigh the mass of water required to fill the egg.

5.3 State of incubation

Different methods have been used to estimate egg incubation stage. Candling the egg to determine the growth of the air cell and/or embryo was evaluated by Westerkov (1950) for game bird eggs. He warns of the difficulties of using this method for small, thick-shelled or dark coloured eggs. Methodological procedures are explained in Weller (1956) and Sobkowiak (1984). Collared pratincole eggs are both small and dark coloured which does not make this method advisable.

Other methods involve the use of egg density. This varies during the incubation period due mostly to the loss of water which for many species is constant during this period (Ar & Rahn 1980). For some passerine species an increase in the rate of water loss has been found (Carey 1979, Sotherland *et al.* 1980). I will assume a constant rate of water loss during incubation and a total weight loss of 15% at the end of it (Ar & Rahn 1980). A way of determining incubation stage using density is immersing the egg in water, ranging from a horizontal position on the bottom of the water at laying to a vertical angled position floating on the surface before hatching (Westerkov 1950, Schreiber 1970, Hays & LeCroy 1971, Dunn *et al.* 1979, Nol & Blokpoel 1983, Van Paassen *et al.* 1984, Carroll 1988). Another way of determining incubation stage based on density and the one used in this study was described by Furness & Furness (1981). Egg density was plotted against days to hatching. The regression equation obtained gives the stage of incubation from the egg density on the day the egg was weighed. A total of 38 clutches of known hatching date were used to calculate the regression of mean clutch density and days the clutch had been incubated. This was calculated assuming an incubation period of 18 days (Cramp & Simmons 1983).

Hatching date was used as a time reference as it was obtained for many nests by direct observation and it is therefore a precise variable. For nests that did not hatch successfully the state of incubation was calculated from egg density and the expected hatching date obtained from this.

5.4 Fresh egg weight

Considering a constant weight loss of 15% through the incubation period and knowing the stage of incubation (obtained as explained above), egg weight at the beginning of incubation

(FW) was calculated. Weight loss (WL) at the moment the egg was found and weighed was WL = DIN × 15/18 (DIN=days of incubation) and so, FW = (W×100)/(100-WL) where W is the weight obtained in the field when found.

5.5 Egg contents

Fourteen fresh eggs were hard boiled and weighed. Yolk and albumen were separated, weighed and dried to constant weight by keeping them in an oven at 60°C. They were re weighed to determine water loss. Lipids were extracted in a Soxhlet at 100-150°C using chloroform as a solvent. They were dried to constant weight again to determine the lipid fraction in them. The remaining weight was considered solids (proteins, carbohydrate and inorganic compounds). Shells are not considered. Albumen increased in weight after going through the lipid extraction process (0.015g, SD=0.01). To check for anything binding to the envelopes, twenty one empty envelopes (as the ones used for wrapping the albumen and yolk) were dried, weighed and put through the Soxhlet. After drying to constant weight again a slight increase in weight was obtained (0.001g, SD=1.3×10^{-3}). Weight increase due to the envelopes was very small and the result obtained for the albumen could be due to proteins binding contaminants in the chloroform. Lipid content in the albumen would have been very small and this slight increase masks it. In the yolk the lipid content is high enough to show a pronounced decrease in weight. For this reason solid and lipid percentages are given together for albumen. For whole egg contents, a minimum lipid percentage was calculated using the lipid content in the yolk. The actual number will be very similar as the amount of lipid in the albumen is very small.

6. CHICKS

Attendance, number of times chicks were fed by adults, and chick growth, were studied in marshland and farmland colonies in the marshes of the Guadalquivir river. Chicks were classified into one of these three age-classes:

1. Less than one week old. Chicks covered in down.
2. Medium. First feathers visible, not downy appearance anymore.
3. Nearly or very recently fledged but still dependent on parents' food. No down left. Able to fly short distances close to the ground.

All three classes of chick were extremely cryptic and hid when parents detected a potential predator, so that random search for chicks proved unrewarding.

1. Attendance. Parent's attendance was recorded in both types of habitat. Observations (47 one hour observations) were carried out from 10.00 to 13.00 hours. It is assumed that if the adults were not with the chicks they were foraging for their broods or for themselves, and an index of foraging activity was deviced as:

F.i.= (Time both adults away+1/2 time one adult away)/Total time

This index was analysed in relation to the habitat where the chicks came from, brood size and brood age, with a three way ANOVA.

2. Number of chick-feeds. Adults feed their chicks all through their development. If a brood of more than one chick was followed, it was assumed that all the chicks in the brood were fed an equal number of times and therefore, the total feeds observed was divided by the brood size. A total of 70 observation hours was accumulated with all observations made between 10.00 and 13.00.

3. Growth. Weight was plotted against head plus bill and wing length and curves fitted to both. Chicks from colonies in marshland and farmland were plotted separately within the same graph and both regression equations were calculated, with the aim to compare growth in both habitats, using the linear body measure as an index of age. Differences between 1992

and 1993 were also tested. In 1993, data from 20 chicks from a marshland colony located further inland were taken and compared to those in the area of the marshes of the Guadalquivir river.

RESULTS

1.PHENOLOGY

Collared pratincoles start to arrive in the study area at the end of March, first to the Guadalquivir marshes (also the ones reclaimed at present), and later on to the colonies further inland. During this period they can be found at temporary pools or lagoons, meadows or recently ploughed fields. The number of individuals in these places fluctuates from day to day and within the same day. Pratincole activity at this period is mainly related to feeding, resting and courtship displaying. Dispersion to colony sites occurs from March to the first half of May, the peak being during the first two weeks in April (Fig. 3.1). Odd colonies may be formed at the beginning of May. Pattern of arrival to the colonies was similar in all years. Although the first colonies to be occupied were some colonies in marshes, no association was found between the arrival times (before and after 15 April) and the type of habitat (marshland or farmland) (X^2=0.53, n=31, df=1, N.S.).

Laying starts at mid April, the peak being around the first week in May. There is a high nesting synchrony in pratincoles. Most of the clutches were laid within a few days in the marshland colony and the farmland colony (Fig. 3.2). The hatching peak is at the end of May. Chicks are able to walk around in a few hours and when all the eggs have hatched the adults and their brood move away from the nesting site. Fledging takes around one month.

Departure from the colonies starts in June, most of the colonies being empty at the end of July (Fig. 3.3). No association was found between type of habitat and departure time from colonies (X^2=0.02, n=49, df=2, N.S.).

Adult and juvenile pratincoles may form post-breeding aggregations before migration. In 1988 these aggregations were formed mainly in a few rice fields which had not been successful but remained flooded. They started to concentrate there at the beginning of July with a peak at mid July (2574 individuals) and the last ones were observed at the end of September. In 1989 they were observed for a short period in dry rice fields that were being levelled or ploughed, sometimes in association with cattle egrets *Bubulcus ibis*. Maximum numbers registered were usually under 200 individuals. The peak number was 1500 in a rice field around the 1st of August. Aggregations started to form in July and by mid August there was hardly any birds left.

2. COLONIES

2.1 Colony size, area and density

There was no significant difference between marshland and farmland colonies in colony size (number of individuals per colony) (Tables 3.1 and 3.2, T-test, t=0.99, df=54, N.S. for 1989 and t=-0.55, df=58, N.S. for 1990). Numbers did not differ between years in either habitat (T-test, t=0.38, df=50, N.S. for marshland colonies and t=-1.05, df=62, N.S. for farmland colonies).

Colonies in marshland and farmland did not differ significantly in area (Table 3.1, T-test, t=-0.99, df=43.83, N.S.) or in density (number of individuals in the colony divided by the estimated colony area, Table 3.1, T-test, t=0.25, df=51, N.S.).

2.2 Vegetation cover

Vegetation cover in farmland was zero at the time of settlement except for a few fields in which the plants had already started to grow, usually not more than 10 cm. Vegetation (separated into tussock and grass) height and cover for colonies in marshland are shown in Table 3.3. There were no significant differences in tussock cover (T-test, t=1.81, df=33.73, N.S.), tussock height (t=1.21, df=39, N.S.) and grass height (t=0.17, df=26.31, N.S.), but grass cover was significantly denser in 1990 than in 1992 (Mann-Whitney, U=76.5, Z=-2.86, n=37, p<0.005).

Table 3.1 - Characteristics of pratincole breeding attempts in marshland and farmland colonies. Mean±se (n).

	MARSHLAND	FARMLAND
COLONIES		
1989		
Colony size (number of individuals)	69.8±11.94 (21)	60.3±11.41 (35)
1990		
Colony area (ha)	4.7±0.99 (27)	4.4±0.57 (26)
Colony size (number of individuals)	63.1±9.97 (31)	67.4±10.04 (29)
Colony density (size/ha)	19.4±2.39 (27)	18.0±2.34 (26)
NESTS		
Nest spacing (m)	19.0±0.86 (50)	22.3±1.01 (47)
EGGS		
Clutch size		
% Small clutches (1-2 eggs)	26..5% (13)	47.7% (21)
% Big clutches (3 eggs)	73.5% (36)	52.3% (23)
Clutch volume (ml)	8.6±0.08 (43)	8.3±0.12 (22)
Clutch weight (g)	9.3±0.10 (42)	9.2±0.14 (17)
CHICKS		
Number of chicks feeds	4.7±0.46 (35)	5.0±0.43 (35)
Chick measurements 1992		
Head plus bill (mm)	33.8±0.82 (48)	33.3±0.79 (38)
Wing length (mm)	73.2±5.36 (48)	70.7±6.24 (38)
Weight (g)	40.4±2.38 (48)	39.9±2.48 (38)
Chick measurements 1993		
Head plus bill	36.2±1.23 (18)	38.1±0.62 (32)
Wing length	91.0±10.50 (18)	101.8±5.65 (32)
Weight	46.6±4.19 (18)	50.8±2.14 (32)
Hatching success		
Marshland 1/Farmland 1	90.9% (47)	34.7% (49)
Marshland 2/Farmland 2	72.7% (9)	12.5 (16)

Table 3.2 - Percentage of pratincole colonies with different colony sizes (number of individuals per colony) in farmland and marshland colonies.

Individuals/ colony	Marshland 1989	Farmland 1989	Marshland 1990	Farmland 1990
<25	28.6	34.3	29.0	27.6
26-50	19.0	34.3	25.8	20.7
51-100	28.6	17.1	25.8	31.0
>100	23.8	14.3	19.4	20.7
N	21	35	31	29

Table 3.3 - Vegetation cover (%) and height (cm) in colonies in marshland.

	Tussock cover		Tussock height		Grass cover		Grass height	
	1990	1992	1990	1992	1990	1992	1990	1992
Mean	14.8	8.5	21.6	18.3	53.4	24.2	6.5	6.3
Se	2.87	1.90	1.79	2.08	5.61	7.01	0.57	1.25
N	21	20	21	20	17	20	17	20

2.3. Influence of vegetation cover on other parameters (marshland colony).

There were two distinct cover areas, one with less than 3% vegetation cover, and another with 10 to 15% vegetation cover. Vegetation height, measured as the maximum plant height, was practically uniform in the whole colony, from 11 to 22 cm.

There were no significant differences in nest spacing (T-test, t=0.63, df=48, N.S.), clutch size (Chi-square, X^2=0.29, n=49, df=1, N.S.), mean clutch volume (T-test, t=-1.08, df=41, N.S.)

or hatching date (T-test, t=-1.66, df=47, N.S.) in areas with lower and higher tussock cover within the colony (Table 3.4). A significant difference was found in the mean initial weight of clutches in both cover areas, clutches being heavier in the denser areas (Table 3.4, T-test, t=-2.85, df=40, p<0.01).

Table 3.4 - Mean ±se (n) pratincole nest spacing, clutch size, volume, weight, and hatching date in the two distinctive vegetation cover areas in the colony in marshland.

	< 3% COVER	8-15% COVER
Nest spacing (m)	19.5 ±1.09 (25)	18.4 ±1.35 (25)
Clutch size	2.6 ±0.11 (25)	2.7 ±0.09 (24)
Clutch volume (ml)	8.5 ±0.12 (22)	8.7 ±0.10 (21)
Clutch weight (g)	9.1 ±0.12 (21)	9.6 ±0.13 (21)
Hatching date	13.5 ±0.84 (24)	15.9 ±1.21 (25)

3. NESTS

3.1 Nest structure

Collared pratincoles make a scrape on the ground. Both members of the pair scrape with their legs, turning around the cup of the nest. They may make several scrapes before the definitive one. Most of the nests have no lining at all, but some have little stems, pebbles or dry mud bits. Combining the data found from 1989-1992 (n=159), 80% of the nests were just a simple scrape (Table 3.5). There is a highly significant association between types of habitat and nest type (Chi-square, $X^2=35.57$, df=1, n=159, p<0.01). In marsh 97.7% of the nests were simple scrapes whereas only 58.3% were unlined scrapes in farmland.

Table 3.5 - Percentage of pratincoles' nests with and without added material.

	Marshland	Farmland	Total	N
Normal	97.7%	58.3%	79.9%	127
Added material	2.3%	41.7%	20.1%	32

3.2 Nest dispersion

Distribution of nests in both colonies does not depart from random (X^2=6.8, df=5, N.S. in the marshland colony and X^2=6.52, df=7, N.S. in the farmland colony).

3.3 Nest spacing

Nests were slightly closer to each other in the marshland colony than in the farmland one (Table 3.1, T-test, t=-2.67, df=95, p<0.01). There is no significant association between clutch size and nest spacing in either colony (Table 3.6, Chi-square, X^2=0.79, df=2, n=49, N.S. for the colony in marshland, Chi-square, X^2=0.35, df=2, n=43, N.S. for the colony in farmland). Pratincoles nesting closer to other pratincoles did not lay bigger or heavier eggs in the colony in marshland (r=-0.04, n=43, N.S. for mean clutch volume, r=0.00, n=42, N.S. for mean clutch initial weight) or the colony in farmland (r=0.06, n=22, N.S. for clutch volume and r=0.19, n=17, N.S. for clutch weight). There was no correlation between nest spacing and hatching date (r=0.13, n=50, N.S. for the colony in marshland and r=-0.04, n=45, N.S. for the colony in farmland).

Table 3.6 - Mean±se (n) pratincole clutch size in the marshland colony and the farmland colony at different distances from other pratincole nests.

	< 15.5 M	15.5-21.5 M	>21.5 M
Marshland colony	2.7 ±0.11 (18)	2.8 ±0.11 (15)	2.6 ±0.12 (16)
	< 19 M	19-23 M	>23 M
Farmland colony	2.7±0.21 (15)	2.4±0.16 (16)	2.2±0.27 (12)

4. EGGS

4.1 Egg volume and stage of incubation

A value of 0.482 (SD=0.005) was obtained for Kv, which allows estimation of egg volume from linear measurements. The equation of the regression of egg density against days to hatching was: MCD = 1.078 + DIN × -0.0069 ($r^2=0.36$, $p<0.001$), where MCD is mean clutch density and DIN is days the clutch had been incubated. The error is 3.41 days (SD=2.41). With this formula days that clutches of unknown laying date had been incubated were calculated.

4.2 Clutch size

4.2.1 Habitat

Collared pratincoles normally lay 2 or 3 eggs (Fig. 3.4). There is no statistical association between clutch size and habitat (Table 3.1, Chi-square, $X^2=3.52$, n=93, df=1, N.S.).

4.2.2 Year

No association was found between clutch size in marshland and year in which the clutch was laid (Chi-square, $X^2=4.46$, df=2, n=92, N.S.). There are not enough data available for clutches from colonies in farmland to compare among years.

4.2.3 Season

In both habitats larger clutches were laid at the middle of the laying period. This difference was not significant in farmland (Table 3.7, Chi-square, X^2=2.22, n=44, df=2, N.S.) but it was in marshes (Table 3.7, Chi-square, X^2=8.09, n=49, df=2, p<0.05).

Table 3.7 - Percentage of small (1-2 egg) and big (3 eggs) pratincole clutches during the breeding period. Time periods were divided in order to get the closest sample sizes in all the groups.

	MARSHLAND COLONY			FARMLAND COLONY		
	13 May-25 May	26 May-28 May	29 May-10 June	17 May-27 May	28 May-31 May	1 June-5 June
Small clutches	42	0	31.5	50	33	60
Big clutches	58	100	69.5	50	67	40
N	19	14	16	14	15	15

4.3 Clutch volume and weight

4.3.1 Habitat

Mean clutch volume was significantly higher in the marshland colony than in the farmland colony (Table 3.1, T-test, t=2.39, df=68, p<0.05).

4.3.2 Year

As for clutch size, only data from marshland colonies will be presented. Data for 1990 are not sufficient, so comparisons are made between 1989 and 1992. Neither clutch volume nor clutch weight differed between them (T-test, t=0.08, df=59, N.S. for volume and t=-0.22, df=56, N.S. for weight).

4.3.3 Season

There was no correlation between mean clutch volume and laying date (r=0.12, n=43, N.S. in marshland and r=0.07, n=22, N.S. in farmland). The same occurred with mean clutch weight (r=0.14, n=42, N.S. for marshland and r=0.12, n=17, N.S. for farmland).

4.3.4 Clutch size

Eggs in smaller clutches were bigger and heavier than eggs in bigger clutches in marshland (Table 3.8, T-test, t=2.36, df=41, p<0.05 for volume and t=2.72, df=40, p<0.05 for weight). In farmland there were no differences in either variable (Table 3.8 t=-0.21, df=20, N.S. for volume and t=1.75, df=15, N.S. for weight).

Table 3.8 - Mean ±se (n) pratincole egg volume (ml) and weight (g) of small (1-2 eggs) and big (3 eggs) clutches in the marshland and farmland colonies.

	Egg volume	Egg weight
MARSHLAND		
Small clutches	8.9±0.13 (9)	9.8±0.20 (9)
Big clutches	8.5±0.09 (34)	9.2±0.10 (33)
FARMLAND		
Small clutches	8.3±0.24 (8)	9.8±0.17 (4)
Big clutches	8.3±0.15 (14)	9.2±0.18 (13)

4.4 Egg contents

The percentage of the various egg components is shown in Table 3.9 (see next page).

5. CHICKS

5.1 Adult attendance

Brood size and habitat did not have any effect on adult attendance (Three-way ANOVA, F=2.77, df=1,36, N.S. and F=0.00, df=1,36, N.S. respectively), but chick age did (Table 3.10, F=20.89, df=2,36, $p<0.001$). Differences are between age class 1 and age classes 2 and 3, and age class 2 with age class 3 (LSD test, $p<0.05$ for all). The older the chicks the less time adults spent with them. No interactions were detected.

5.2 Number of chick feeds

Feeding rate was not affected by habitat or by chick age (Tables 3.1 and 3.10, two-way ANOVA, F=0.34, df=1,64, N.S. and F=1.35, df=2,64, N.S. respectively).

Table 3.10- Mean (±se) attendance (adults foraging index) and number of feeds per hour to pratincole chicks of different age. Age 1=less than one week old, Age 2=medium, Age 3=nearly or recently fledged but still dependent on parents food.

	AGE 1	AGE 2	AGE 3
FORAGING INDEX	0.5±0.05	0.7±0.03	0.9±0.03
N	12	15	20
NUMBER OF FEEDS	5.3±0.42	5.1±0.53	4.1±0.66
N	24	24	22

Table 3.9 - Composition of pratincole eggs. Percentages of egg content. Mean (sd).

NUMBER OF EGGS	14
EGG CONTENT WEIGHT (Yolk+Albumen)	7.7g (0.65)
FRESH EGG CONTENT	
% YOLK	44.8 (5.12)
% ALBUMEN	55.2 (5.12)
YOLK	
% WATER	64.3 (3.94)
% LIPID	21.2 (2.87)
% SOLIDS	14.4 (1.46)
ALBUMEN	
% WATER	87.9 (1.34)
% SOLIDS + LIPID	12.1 ----
WHOLE EGG CONTENTS	
% WATER	76.4 (1.70)
% SOLIDS	23.5 ----
% LIPID (Only yolk)	9.5 ----
YOLK/ALBUMEN RATIO	0.8 (0.17)

5.3 Chick growth

Mean measurements of chicks caught in each habitat are shown in Table 3.1. Figures 3.5 and 3.6 show chick growth in marshland and farmland. In both cases the curves of chick mass on wing length and chick weight on head plus bill (linear measurements as a proxy for chick age) were almost identical in both habitats. Chicks from both habitats were growing similarly. Due to the obvious similarity of both curves in 1992, no further statistical analysis to test for differences was carried out. In 1993 analysis of covariance showed chicks from marshland and farmland colonies were also growing similarly (F=0.26, df=1,47, N.S. for the regression lines of weight on head plus bill and F=1.44, df=1,47, N.S. for weight on wing length). As no differences in curves elevation were obtained, data from chicks from marshland and farmland were grouped to compare growth in both years. Again, no differences were found (Fig. 3.7, F=1.29, df=1,132, N.S. for weight on wing length). For the lines of weight on head plus bill a difference in slope was obtained (F=6.66, df=1,132, $p<0.05$) and, therefore, elevations could not be compared. Regression equations and coefficients of determination are shown in Table 3.11 (see page 38).

Chicks in the marshland colony located further inland were growing less well than chicks in marshland and farmland in the marshes of the Guadalquivir river, but differences were only significant when comparing growth between chicks from marshland colonies (Fig. 3.5 and 3.6, F=14.01, df=1,35, $p<0.005$ for head plus bill and F=17.88, df=1,35, $p<0.001$ for wing length).

6. OTHER BREEDING SPECIES

Collared pratincoles sometimes nest with other species mainly when breeding in marshland (Table 3.12). Kentish plovers *Charadrius alexandrinus* and stilts were the most common species forming mixed colonies with pratincoles in the study area.

In the marshland colony, stilts, stone curlews *Burhinus oedicnemus* and pratincoles nested together. Stilt incubation period is some 24 days (Cramp & Simmons, 1983) and pratincoles' is around 18 days. The hatching peak is 6 days later for stilts which means that both species have their laying peak at the same time. Figure 3.8 shows the hatching periods for pratincoles and stilts. Three stone curlews' nests were started during the pratincoles' breeding period. Stone curlews nests were at the edge of the colony. Stilts were mostly concentrated in an area of the colony where there was less vegetation (Table 3.13, T-test, t=-5.80, df=32.61, p<0.001).

Table 3.12 - Number of colonies in which collared pratincoles nested together with other wader or waterfowl species in 1989 and 1990.

	1989		1990	
	Farmland	Marshland	Farmland	Marshland
Kentish plover (*Charadrius alexandrinus*)	4	9	2	12
Redshank (*Tringa totanus*)	3	2	0	1
Lapwing (*Vanellus vanellus*)	0	1	0	1
Stilt (*Himantopus himantopus*)	9	9	2	18
Avocet (*Recurvirostra avosetta*)	1	0	0	3
Stone curlew (*Burhinus oedicnemus*)	1	5	2	8
Little tern (*Sterna albifrons*)	0	1	0	1
Pintail sandgrouse (*Pterocles alchata*)	4	3	0	6
Mallard (*Anas plathyrrhynchos*)	0	1	0	2
None	26	3	13	6
No data	0	0	10	8

Table 3.13 - Mean (±se) stilt nest spacing in the two distinctive vegetation cover areas in the marshland colony.

	<3% COVER	8-15% COVER
Mean	29.2	96.3
Se	4.58	10.63
N	25	25

There was no difference in pratincole clutch size at different distances from stilt nests (Table 3.14, Chi-square, X^2 =1.81, df=2, n=50, N.S.). There was no correlation either between the latter and pratincole hatching date (r=0.13, n=49, N.S.), pratincole mean clutch volume (r=0.02, n=43, N.S.) or mean clutch weight (r=0.27, n=42, N.S.). Pratincole clutch losses (2 abandoned and 2 taken by predator) were too few to be related to proximity to stilt nests.

Table 3.14 - Pratincole mean (±se) clutch size at different distances from stilt nests in the marshland colony.

	<25 M	25-75 M	>75 M
Mean±Se	2.6±0.13	2.8±0.09	2.8±0.17
N	14	18	18

Table 3.11 - Regression equation and coefficient of determination (r^2) for the curves in figures 3.5 to 3.7.

Figure	Year	Age index	Habitat	Regression equation	r^2
3.5	1992	Head plus Bill	Marshland	$y=-242.881 + 185.986\times\log(x)$	0.799
3.5	1992	Head plus Bill	Farmland	$y=-251.736 + 191.988\times\log(x)$	0.735
3.5	1993	Head plus Bill	Marshland	$y=-340.878 + 249.323\times\log(x)$	0.908
3.5	1993	Head plus Bill	Farmland	$y=-349.457 +253.547\times\log(x)$	0.769
3.5	1993	Head plus Bill	Inland	$y=-378.042 + 268.230\times\log(x)$	0.725
3.6	1992	Wing lenght	Marshland	$y=-56.943 + 54.419\times\log(x)$	0.945
3.6	1992	Wing length	Farmland	$y=-55.106 + 53.503\times\log(x)$	0.939
3.6	1993	Wing length	Marshland	$y=-57.993 + 55.649\times\log(x)$	0.946
3.6	1993	Wing length	Farmland	$y=-75.475, + 63.812\times\log(x)$	0.863
3.6	1993	Wing length	Inland	$y=-87.034 + 66.466\times\log(x)$	0.754
3.7	1992	Head plus Bill	Marshland plus Farmland	$y=-247.959 + 189.442\times\log(x)$	0.772
3.7	1993	Head plus Bill	Marshland plus Farmland	$y=-337.547 + 246.457\times\log(x)$	0.836
3.7	1992	Wing length	Marshland plus Farmland	$y=-56.579 + 54.298\times\log(x)$	0.940
3.7	1993	Wing length	Marshland plus Farmland	$y=-63.357 + 57.972\times\log(x)$	0.903

DISCUSSION

1. PHENOLOGY

The temporal pattern of arrival, breeding and departure from the study area is similar to that found in other parts of Europe (Sterbetz 1974). Pratincoles arrived first to the most southern parts within the study area, colonies farther inland being formed later on. The same was found by Dolz *et al* (1989) in eastern Spain.

Sterbetz (1974) said that pairs were probably formed before arriving to the breeding areas. Courtship displays are observed from their arrival. Movements to and from the fields they use before dispersing into the colonies and dispersion to these are not well known. Colony formation in marshland and farmland occurred at the same period of time and, with a few exceptions, in the same terrain as in previous years. These facts support the idea of colony-site fidelity. Csaba (1979) and Sterbetz (1974) suggested this as well, but there is little information on marked birds to clarify this point. One bird ringed in southwest Spain in August 1968 was found dead 11 km away three years later (Fernández 1974). The fact that colonies are formed at the same times in colonies in marshland and farmland also indicates that conditions (e.g. food availability) are similar in both habitats at the time of settlement. But this pattern of colony occupation may not be the same every year. Settlement can be delayed if weather conditions are not good. Armitage (1930 field notes) and Pérez-Chiscano (1965) report how birds were not settled due to strong rainfall (see Chapter 4). Also, if once the colony is formed the clutches are lost, the colony formation procedure can start again or, if they do not find an adequate breeding site or if it is too late in the breeding season, birds can wander around until the others leave (Sterbetz 1974, Csaba 1979).

Departure from colonies occurs once breeding is over. Birds may stay in the area if food availability is good, or else leave it straight away. In dry weather departure occurs earlier (Valverde 1960). In some years high numbers can be seen until September (Ibarra 1966 field notes, 1988 this study) but numbers generally decrease in July and there are hardly any birds left by the end of August.

2. COLONIES

There is no indication of colonies being bigger or more densely populated in either marshland or farmland and, although a fluctuation in number of pratincoles breeding in particular colonies may occur, numbers did not differ between years.

Vegetation cover in marshland colonies was lower in 1992 than in 1990 which could be due to the winter 1991/92 being drier than the winter 1989/90. These values of vegetation cover and height allow pratincole settlement. Denser and/or higher vegetation may deter the birds from settling. This will be discussed in Chapter 4.

Pratincoles settled in the two distinctive areas of vegetation cover in the marshland colony (<3% and 8-15%) did not differ in nest spacing, clutch size or volume, or hatching date. High vegetation cover has been considered to give protection to ground nests by concealing them from predators (Dwernychuck & Boag 1972). Colwell (1992) did not find any relationship between nest concealment by vegetation and nest predation in wilson's phalarope *Phalaropus tricolor*. Hatching success in the marshland colony was high (see Chapter 6) and there were no indications that these values of vegetation cover have any influence on their success. The only two nests destroyed by predators were located in the area with higher cover.

3. NESTS

3.1 Nest structure

Nest material is added to the nest during the nest-relief ceremony when the bird leaving the nest picks up bits of mud, pebbles, stems or other material and throw it over its back onto the nest. Thus, nests have progressively more material on them as the incubation period progresses. Sterbetz (1974) reports birds taking material to the nest to protect it when raining heavily. This was not observed in this area. Most of the nests in marshes did not have added material whereas a high percentage of those in farmland did. Sterbetz (1974) said that it is possible to find nests with and without material in all habitats and Dolz *et al* (1989) suggested that the existence of this material on the nest and its amount varies according to availability in the surroundings. They also suggested that the lack or presence of material is such as not to make nests too visible. This is not the case in many of the nests I found in farmland where (eggs being similar in colour to the soil), adding material of different colour to the nest increases detectability. The idea of nest material helping birds to locate their nests in the crop is not probable as less than half of the pairs had this type of nest and location of nests must be as easy or difficult for all pairs. I suggest that the presence of material depends exclusively on the material around the nest. Concealment of the nest may not be that important here. Effectively, avian predators have never been seen taking eggs in this area, but they have been observed taking chicks which are not in the nests any more (see Chapter 6). Why are there then so few nests with added material on marshland? Probably because no loose material is available to be added, or the material they mainly add in marshland does not give any different appearance to the nest.

3.2 Nest dispersion and density

Nests were randomly distributed in the colony. There was no contagious distribution around a group of stilts nesting in one part of the colony. Nest spacing was higher in the marshland colony. Skeel (1983) found that whimbrels *Numenius phaeopus* nested at higher densities and nesting success was higher in hummock-bog habitat than in sedge-meadow and heath tundra. Predation rate was reduced by joint defence at high nest spacing. Distance to the nearest neighbour was around 215 metres. Pratincole nests were much closer to each other (around 20 metres) and closer in the marshland colony. Communal mobbing of potential avian predators was frequently seen and was vigorous. In studies on lapwings Baines (1990) and Shrubb (1990) found that predation was an important cause of nest failure. In Baines' study the percentage of clutches taken by predators was lower in unimproved areas than in improved ones. The former are more complex habitats making nests less visible. In this study pratincole predation of eggs was rare in either habitat (Chapter 6).

4. EGGS

Collared pratincoles lay one clutch per season (Cramp & Simmons 1983). The chances of having a second brood are few considering the amount of time it takes from egg laying to chick fledging (some 55 days). A second clutch would keep them in the colonies until the end of August, time when most of the birds have already left the area.

Pratincoles' first clutches usually consist of 2 or 3 eggs. Some four-egg clutches have been reported by Makatsch (1950), Beretzk (1954) and Dolz *et al* (1989). These clutches seem to be an exception and the first two authors attribute them to more than one female laying on the same nest. None of the authors give results on the fate of these nests. No four-egg clutches were found in the study area but two nests with five eggs were found. On one nest a second clutch of two eggs was laid on a nest with three eggs that had been incubated for 12 days. One egg was rolled out of the nest. The two-egg clutch hatched and the other eggs were abandoned. Of these, two had no development and the third one only very slight embryo growth. On the other nest a second clutch of two eggs was laid on a nest with three eggs which had been incubated for 8 days. In this case the former three-egg clutch hatched and the second was abandoned.

Maclean (1972) suggested that "the ancestral clutch size of *Charadrii* was four eggs and that taxa whose members lay less than four eggs are younger in evolutionary terms", but he did not explain why this evolution occurred. If pratincoles are able to physically incubate more than three eggs, why is three generally the upper limit? Hills (1980) found that significantly fewer clutches hatched all the eggs when adding a fifth egg to six different wader species with natural clutches of four eggs. He found in experimental nests of spotted sandpiper (*Actitis macularia*) that eggs were less compact than control ones and that heating was uneven within the clutch. Also those taxa within the *Charadrii* in which adults feed their chicks (*Burhinidae*, *Haematopodidae*, *Dromadidae*, *Chionididae* and *Glareolidae*) may lay fewer eggs as adults cannot feed and protect more than three at a time. Safriel (1975), working with semipalmated sandpipers (*Calidris pusilla*), suggested that adults could not offer protection for young when natural four-chick broods were increased to five. Lack (1954,1968) suggested that for species that feed their chicks there is a limit according to the food adults can get for them and, for species in which chicks feed on their own, the eggs are relatively large and the limit would be the ability of females to produce eggs. There has been much discussion of which factor is really limiting the number of eggs in bird clutches (Dobson *et al.* 1988, Briskie & Sealy 1989, Partridge 1989, Rothstein 1990, Arnold 1992, Hardy 1992). Cody (1971) suggested that an increase in the breeding effort in a given season could be selected against because it reduces reproduction in future seasons by more than is gained in a given season. Dobson *et al.* (1988) also considered that selection would favour the clutch size which would maximize the parents' lifetime productivity.

There is also an intraspecific variation in pratincole clutch size: some birds lay two and one-egg clutches and not three-egg clutches. Age and experience (Sæther 1990, Sydeman *et al.* 1991, Forslund & Larsson 1992, Rockwell *et al.* 1993) or some environmental condition (e.g. food availability) (Hiom *et al.* 1991, Bolton *et al.* 1992) have been proved to have effects on clutch size or egg size (Croxall *et al.* 1992). At this point there is not enough information to understand what factors are regulating pratincole clutch size and egg size.

Eggs from smaller clutches were significantly bigger and heavier than eggs from big clutches in marshland, but no relationship was found in farmland. Galbraith (1988b) found the opposite in lapwings nesting in arable land and Rohwer (1988) failed to find any relationship between egg mass and clutch size in waterfowl. A deeper study on this subject would be necessary before drawing any conclusions.

Collared pratincole eggs have large yolks and high lipid content as expected for a species with precocial chicks (Ricklefs 1977, Carey *et al* 1980). Ar & Yom-Tov (1978), for the same species, obtained a smaller percentage of yolk but also within the normal limits for other precocial young, 32% to 57% (Carey *et al.* 1980).

5. CHICKS

Chick performance will be discussed in Chapter 5 in relation to food availability.

6. OTHER BREEDING SPECIES

Kentish plovers and stilts were the most common species breeding alongside pratincoles in the study area. Several papers refer to mixed colonies with the species found in this area and with some others such as common tern *Sterna hirundo* or gull-billed tern *Gelochelidon nilotica* (Valverde 1958, Pérez-Chiscano 1965, Kelemen & Szombath 1975). Only Csaba (1979) has studied some aspects of the interaction between the species. He showed how areas in which pratincole colonies were formed had more pairs of lapwing, kentish plover and black-tailed godwit *Limosa limosa*, and this increase happened once pratincoles were settled. Godwits usually nested in a different habitat in the area and Csaba hypotheses that they change habitat looking for protection. It was beyond the scope of this work to study interactions in mixed colonies, but the possible effects for pratincoles of breeding close to stilts was tested in the colony in marshland. No advantage or disadvantage accrued from nesting close or far from them. Both collared pratincoles and stilts react against disturbances and predators actively, but stone curlews do not. If disturbed during incubation, they walk away from the nest trusting in the crypticity of the eggs. For them nesting in the vicinity of pratincoles and stilts could be an advantage.

Figure 3.1 Accumulative percentage of colonies established by a given date

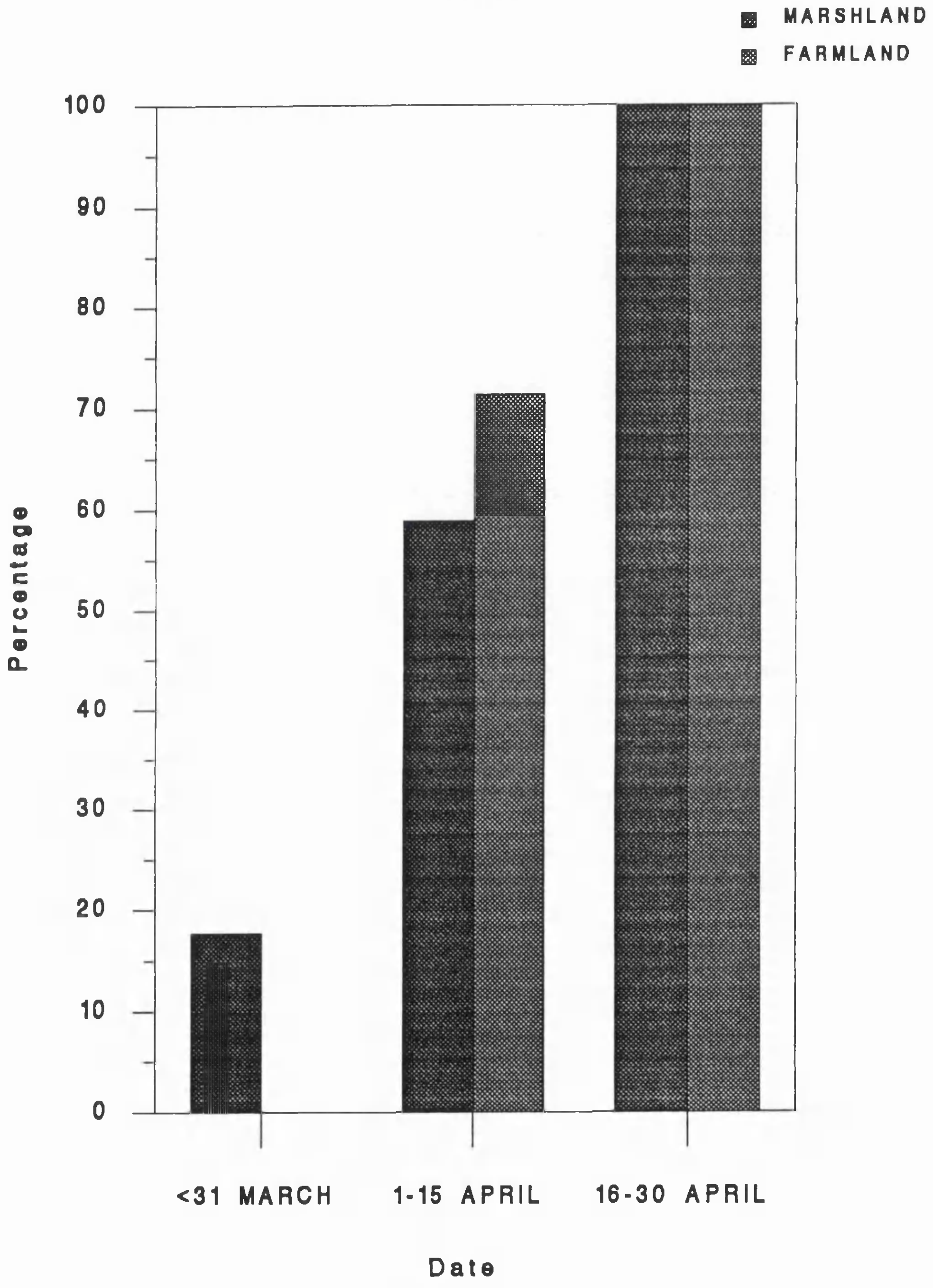


Figure 3.2 Percentage of nests started at different dates

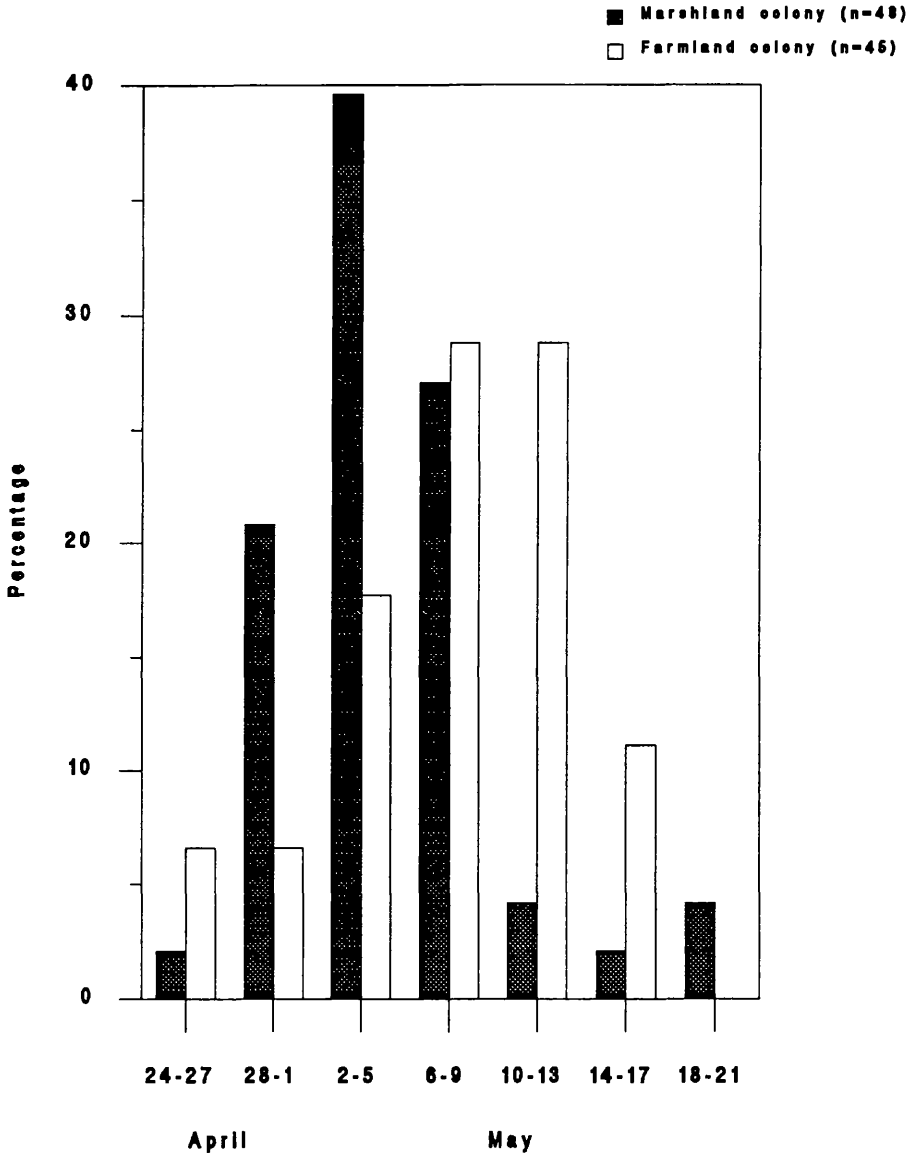


Figure 3.3 Accumulative percentage of departure from colonies

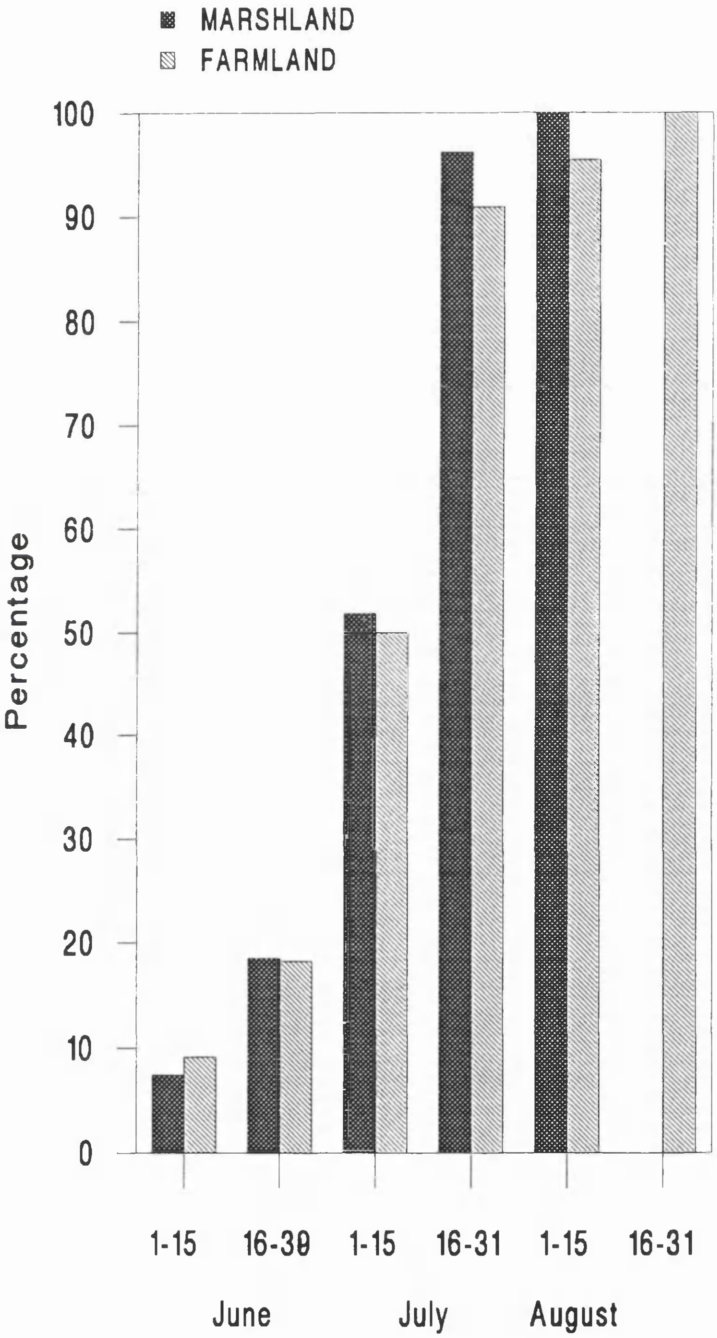


Figure 3.4 Clutch size of pratincoles breeding in a colony in marshland and a colony in farmland

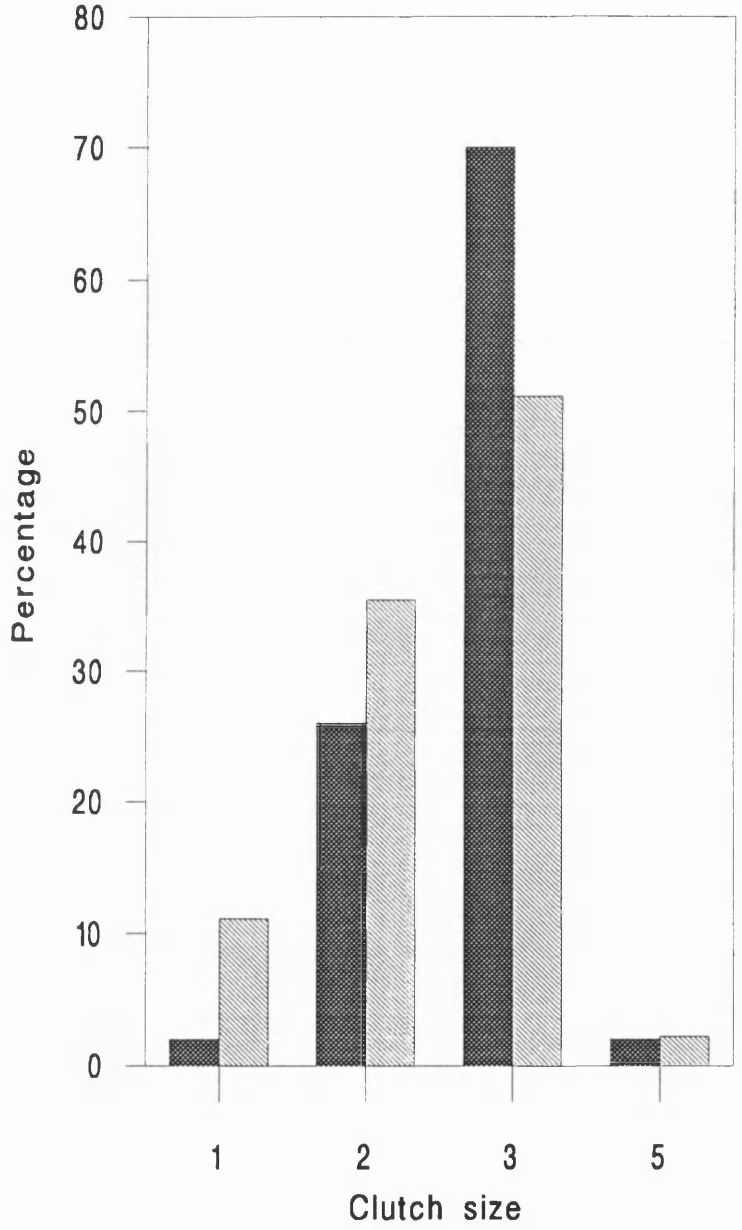
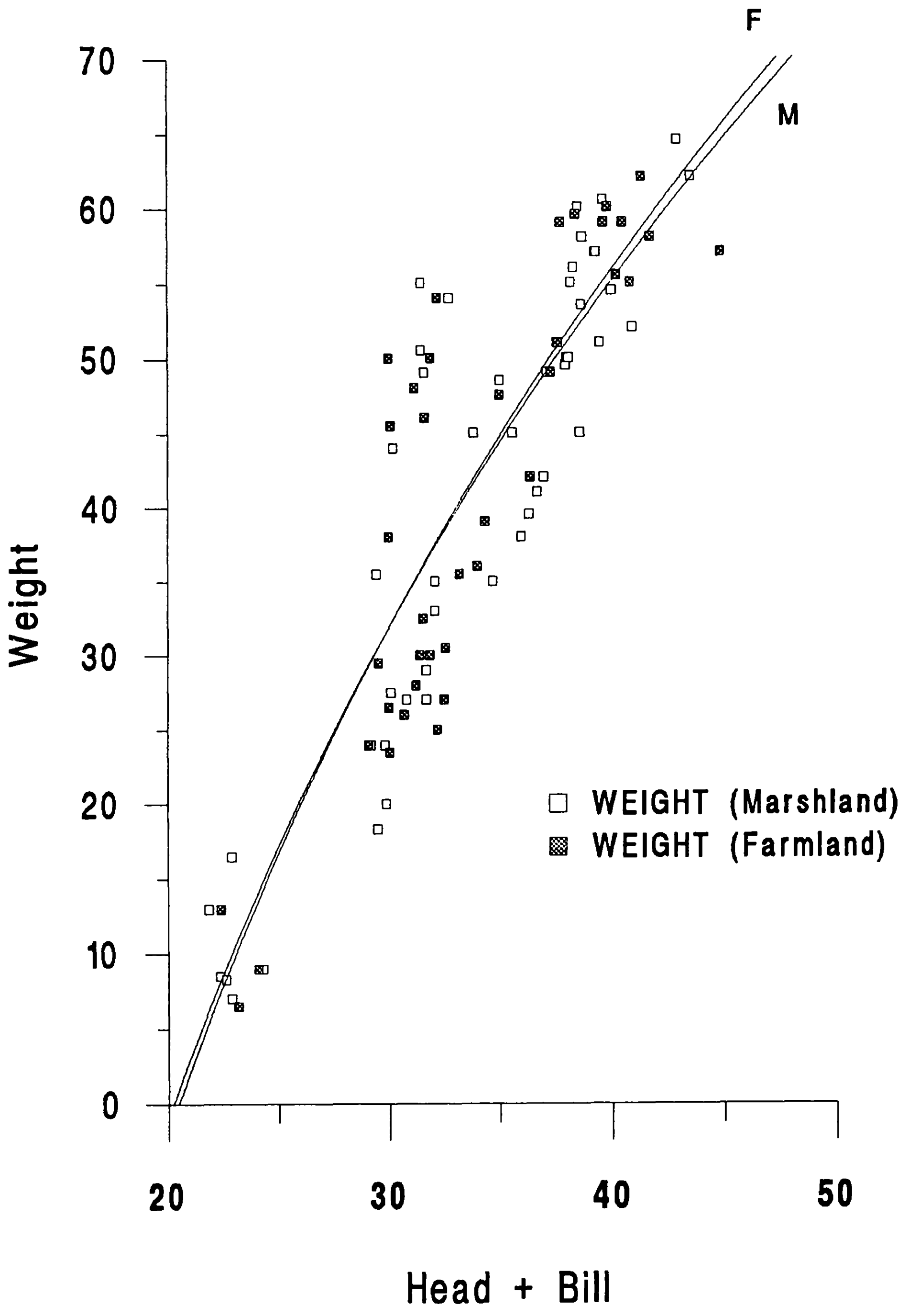


Figure 3.5 - Chick growth in marshland and farmland in 1992 and 1993. Head plus bill (mm) is used as an index of chick age. Equations are given in Table 3.11.

1992


F
M
70
60
50
40
30
20
10
0
Weight
20
30
40
50
Head + Bill
□ WEIGHT (Marshland)
▨ WEIGHT (Farmland)

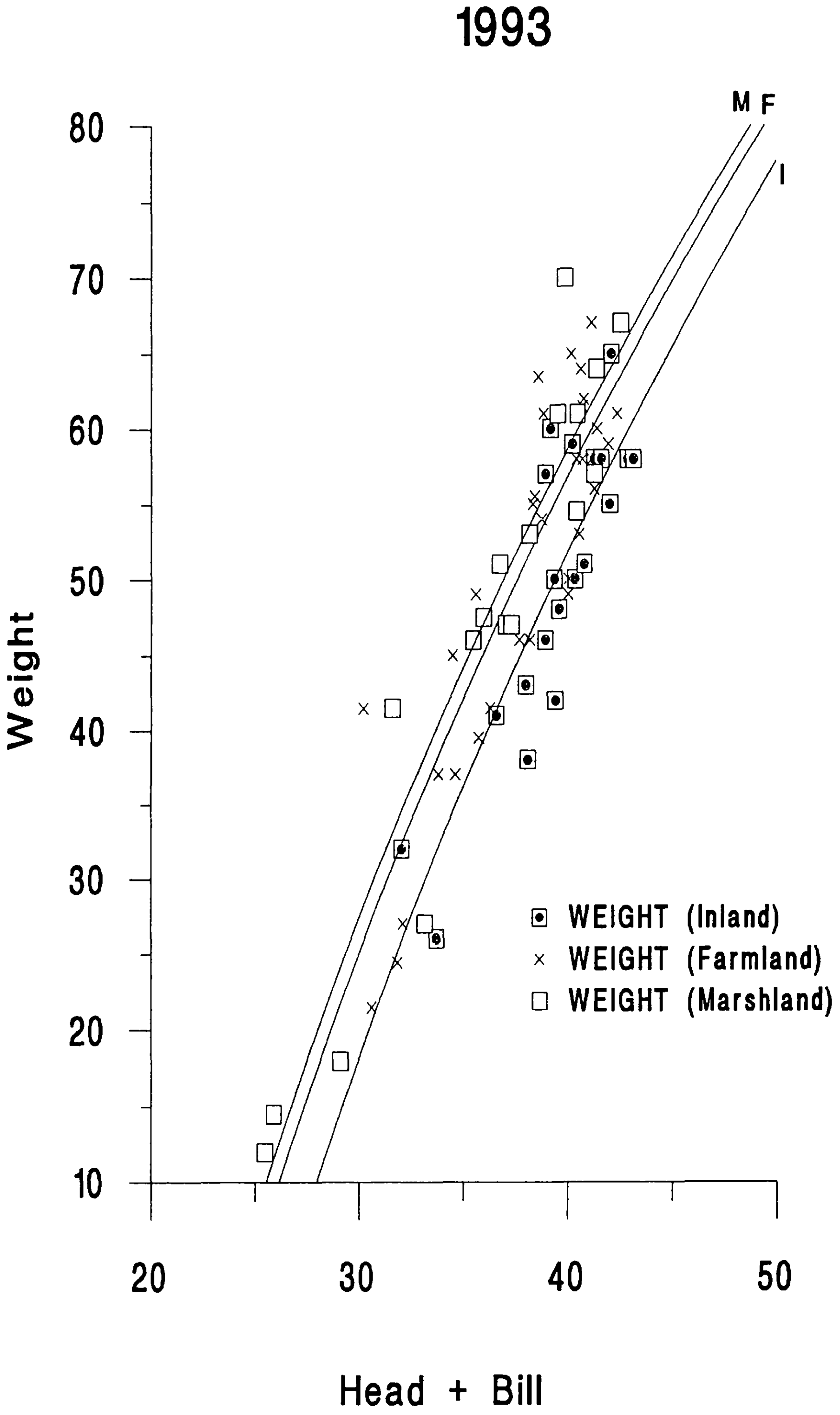
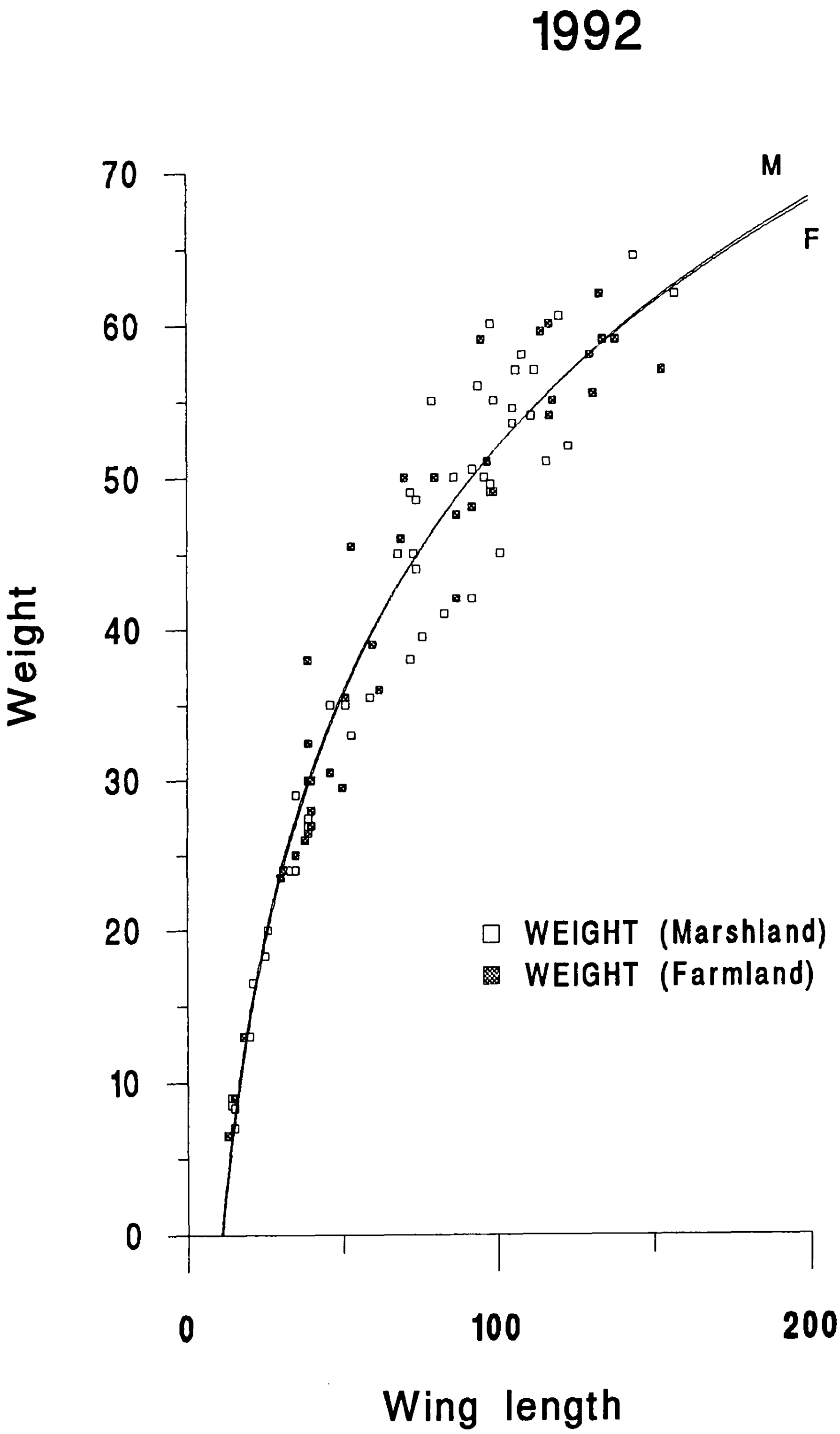
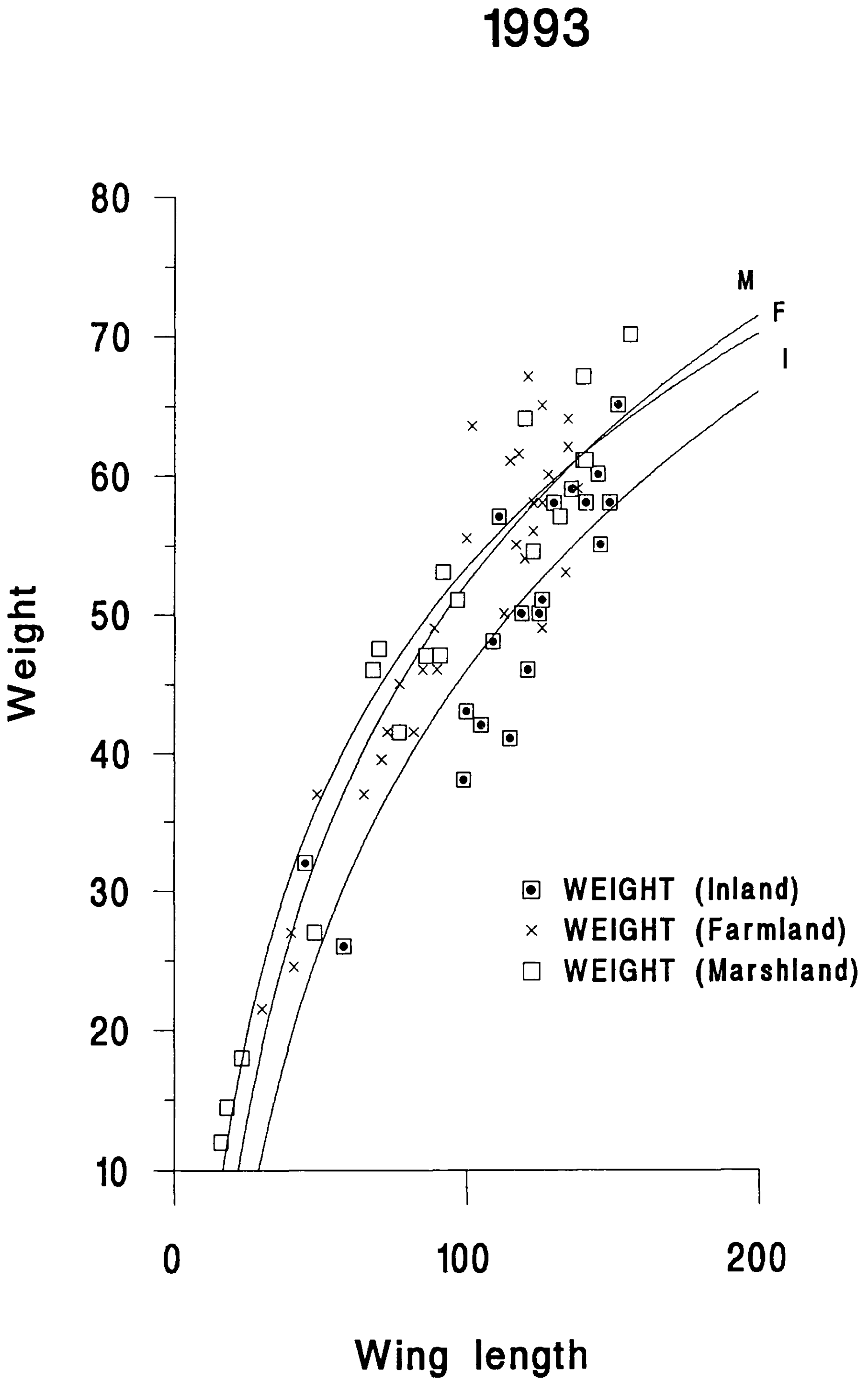

1993
M
F
I
80
70
60
50
40
30
20
10
Weight
20
30
40
50
Head + Bill
WEIGHT (Inland)
WEIGHT (Farmland)
WEIGHT (Marshland)

Figure 3.6 - Chick growth in marshland and farmland in 1992 and 1993. Wing length (mm) is used a s an index of chick age. Equations are given in Table 3.11.



1992

Weight
Wing length
0
10
20
30
40
50
60
70
0
100
200
M
F
□ WEIGHT (Marshland)
▨ WEIGHT (Farmland)


1993
80
70
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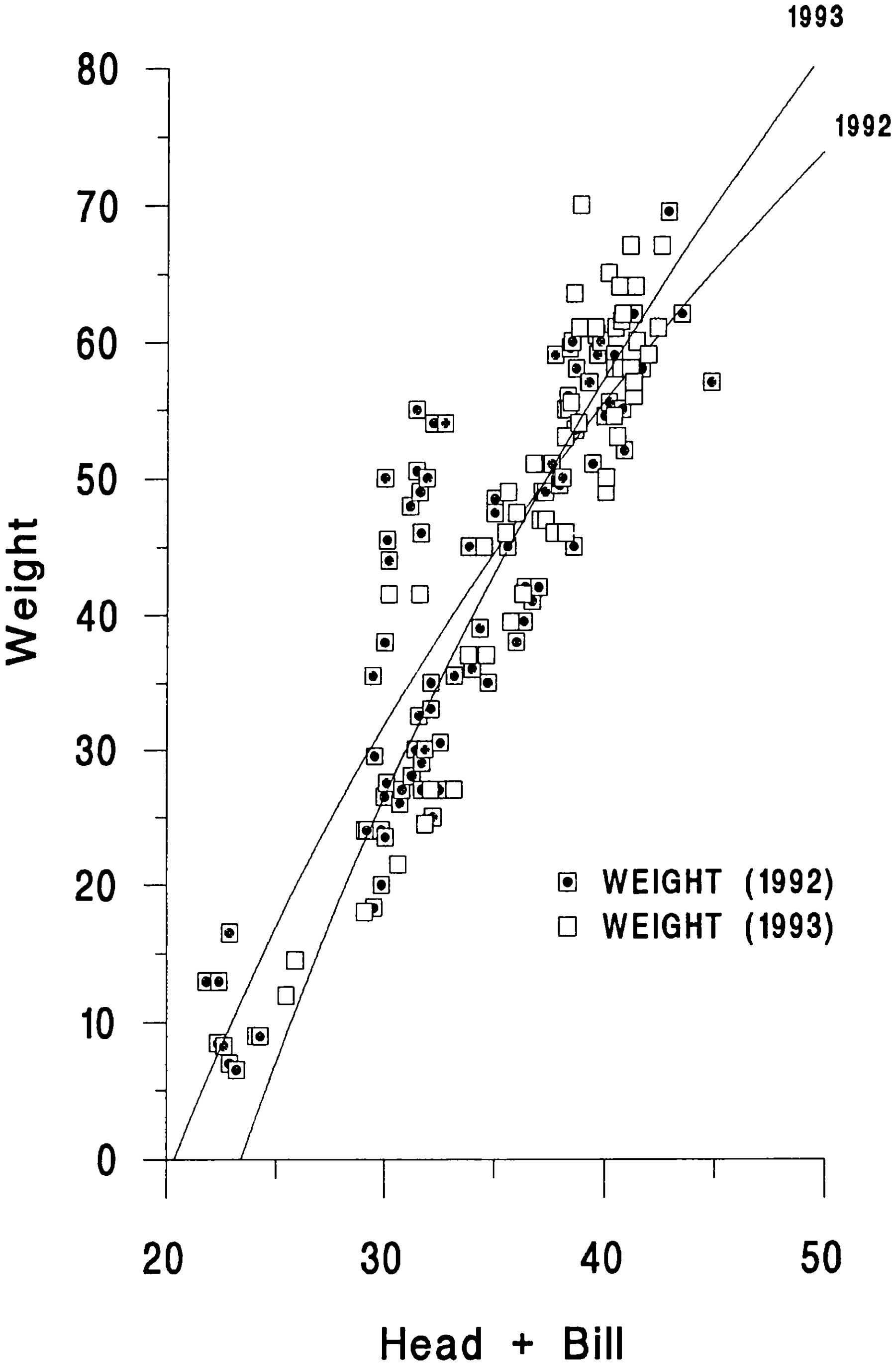
50
40
30
20
10
Weight
0
100
200
Wing length
M
F
I
WEIGHT (Inland)
WEIGHT (Farmland)
WEIGHT (Marshland)

Figure 3.7 - Year comparison (1992 and 1993) of chick growth. Head plus bill (mm) and wing length (mm) are used as indices of chick age. Equations are given in Table 3.11.


1993
1992
80
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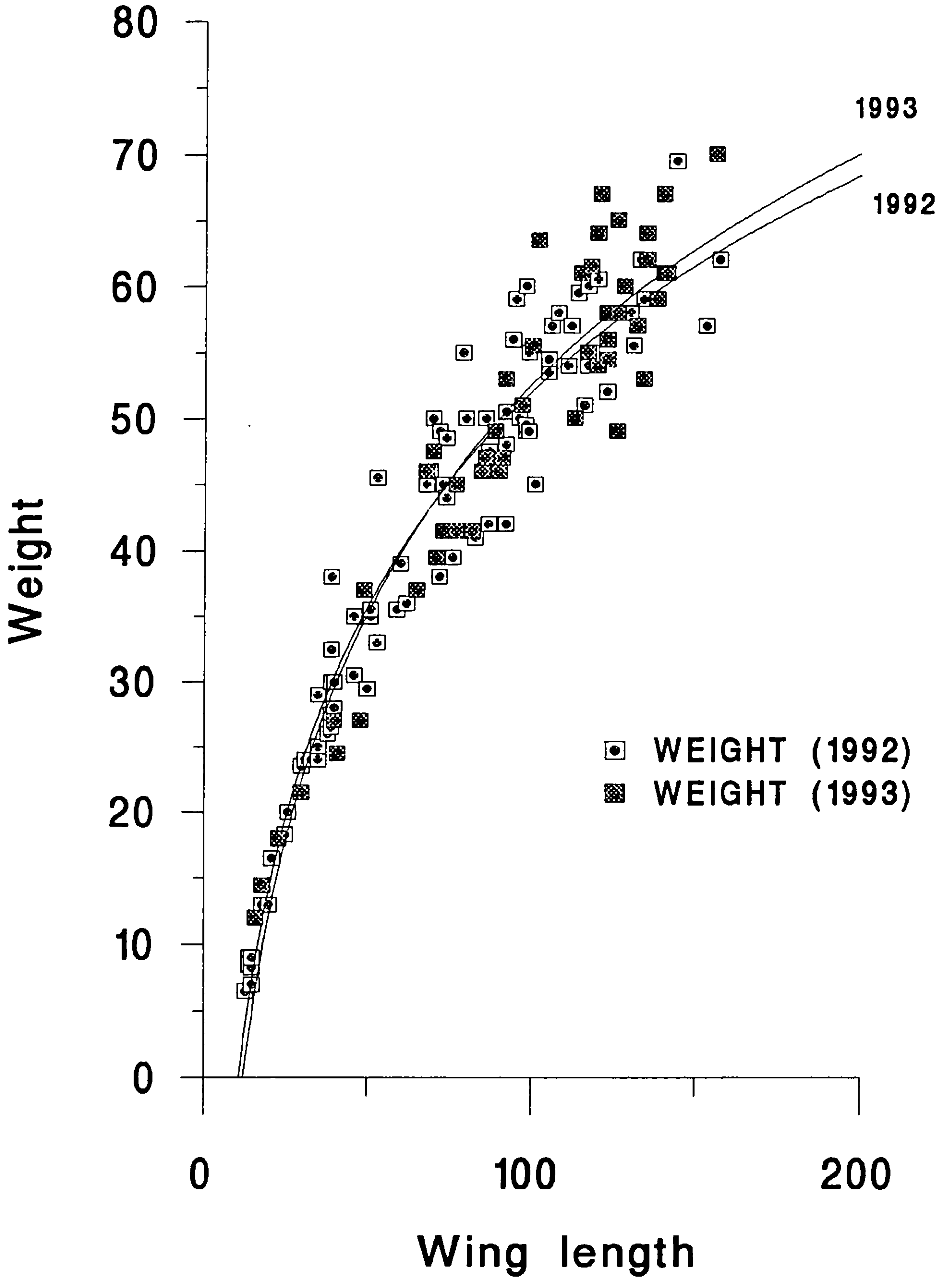
10
0
Weight
20
30
40
50
Head + Bill
WEIGHT (1992)
WEIGHT (1993)


80
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40
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20
10
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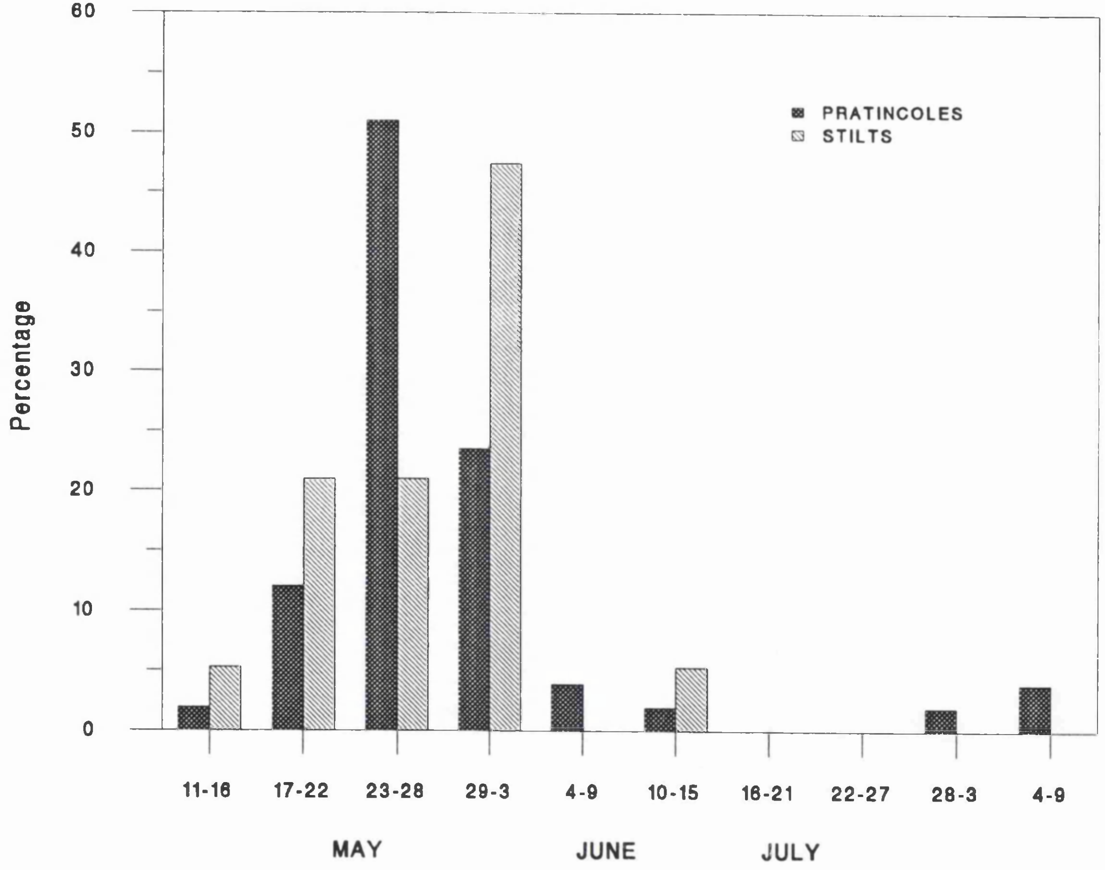
Weight
0
100
200
Wing length
1993
1992
WEIGHT (1992)
WEIGHT (1993)

Figure 3.8 Percentage of nests hatched at different dates in the marshland colony



CHAPTER 4

PRATINCOLE HABITAT SELECTION

INTRODUCTION

Loss of habitat can be a major factor causing bird population decline and this appears to be the case for collared pratincoles (Chapter 1), which at present have an important part of their population breeding on farmland as a result of land-claim of marshes. Studies of habitat selection by other species which breed on farmland have shown that changes in land-use can cause a decline in the breeding population. Lapwings were unable to produce enough young to maintain the population on agricultural land and depended on immigration from populations on upland grassland (Galbraith 1988a).

Berg (1992) showed that a decrease in grassland area and an increase in habitat fragmentation had detrimental effects on curlew *Numenius arquata* breeding and foraging. Corncrakes *Crex crex* are also sensitive to changes in land-use: modifications in the vegetation due to a decrease in the area of hay meadows and an increase in the area of short pastures could explain the general decline of this species (Stowe *et al.* 1993).

General geographical and vegetation characteristics of the breeding habitat of collared pratincoles have been described several times (Valverde 1960, Pérez-Chiscano 1965, Sterbetz 1974, Dolz *et al.* 1989). The same is the case for nest-sites (Valverde 1960, Sterbetz 1974). However, there are no detailed studies of either. As most of the pratincole natural breeding habitat has been reclaimed in the study area (Chapter 1), it is important to know what their breeding preferences are at present, as well as the factors that make them settle in the different habitats they use. This information, together with knowledge of food availability and breeding performance in these habitats, can provide the basis for management of this threatened species.

Hilden (1965) recognized proximate and ultimate factors influencing habitat selection by birds. The former are those stimuli which make birds settle in a given place and which may not be the real reason for birds to settle there (ultimate factors). For instance, lapwing nest density and cow-pat density (proximate factor) were positively correlated (Rankin 1979). Adults and chicks were feeding mainly on dung-associated prey and the total invertebrate biomass was the ultimate factor. Protection from predators and climatic conditions, availability of food and specific requirements depending on the morphology and characteristics of each species were the main ultimate factors cited by Hilden (1965). In this chapter I will analyse the habitat preferences of collared pratincoles in the study area and consider which proximate factors in farmland and marshland determine their selection as colonies and as nesting sites.

A. COLONY SITE SELECTION

METHODS

Available farmland for pratincoles to settle in the study area was calculated with information on agricultural activity obtained from the Agriculture and Fisheries Service of the Junta de Andalucía. Data from all marsh fragments (with and without colonies) were recorded. For colonies in farmland, data were taken from all colonies and from random points in agricultural land. The following data were recorded:

1. Number of pratincoles. The counting method is described in Chapter 3.
2. Vegetation parameters

2.1 Tussock cover. Three 20 m transects were taken through each colony and the number of centimetres with and without vegetation noted down. This was only done in colonies in marshes. Vegetation in the colonies in farmland at the time of settlement is close to zero.

2.2 Tussock height. Maximum height of all tussocks was recorded and the mean used as tussock height.

2.3 Grass cover. As for tussock cover.

2.4 Grass height. As for tussock height.

3. Fences. Presence within the colony, around the colony or absence.
4. Power lines. As for fences.
5. Distance to the nearest feeding area where birds were actually seen feeding, categorised as either less than 100 metres or more than 100 metres from the edge of the colony.
6. Distance to the nearest water resource (irrigation ditches, lagoons, etc.) (<100m or >100m).
7. Distance to the nearest used road (<100m or >100m).
8. Cattle, horses and sheep. Presence or absence.
9. Slope. Flat or slight slope. Only used in farmland as marshes are flat.
10. Origin. Referred to maps dating from 1918, when these wetlands were virtually in their natural state.

Stepwise logistic regression was used for marshland and farmland data analysis. Presence or absence of colonies was the dependent variable. For colonies in marshes the following independent variables were considered: tussock cover and height, grass cover and height (only in 1992), presence of fences and power lines, distance to water resource, distance to road and presence of cattle (only in 1992). Distance to the nearest food resource was highly correlated with distance to nearest water resource and was not included in the analysis. Presence of cattle has influence on the vegetation but there are other factors such as weather condition and human activity influencing it. Therefore, vegetation variables and presence or absence of cattle are both considered. For colonies in farmland presence of fences and power lines, distance to water resource, distance to roads and slope (flat or slight inclination) were the independent variables recorded. Distance to food resource and distance to road were excluded for the same reasons as in marshland. The jack-knife method was used to test the accuracy of prediction of the test. For each test values for the Goodness of Fit (if not significant indicates no departure of data from the model), Model Chi-square (indicates whether significant improvement on the initial model - which contains no variables - has occurred), and the Improvement (indicates if the model has improved since the last step) are given. Comparisons between years were not made as data are not independent.

RESULTS

1. Habitat availability and preference

Collared pratincoles require flat or slightly elevated open areas with little or no vegetation cover. Therefore, not all farmland is suitable for settlement. It has been discussed in Chapter 2 what major crop types could be considered as potential colony sites: herbaceous and rice fields. But within these there are only some crops which are used (Table 4.1, see next page). Effectively pratincoles settle mainly in cotton, sunflower and legume fields (Table 4.2, see page 50). It does not mean that pratincoles select them because they are a specific type of crop, but at the time of settlement those fields present similar characteristics (see below) which allow colony establishment. Rice fields are flooded before spreading the seeds and colonies settled on them are destroyed.

Table 4.3 - Percentage of colonies in marshland and farmland in 1989, 1990 and 1992.

	1989	1990	1992
MARSHLAND	38	55	41
FARMLAND	62	45	59
N	56	64	59

Percentages of colonies in marshland and farmland are given in Table 4.3. There were no significant differences between years (Chi-square, X^2=4.14, df=2, n=179, N.S.). Although there are now more colonies in farmland, its availability is approximately 97% of all the potential colony sites. Therefore, pratincoles select marshes, which hold 40-50% of the colonies but represent only 3% of the area potentially available.

Table 4.1 - Availability of agricultural land for pratincoles in the study area at the time of settlement in 1990. Some sunflower fields are suitable for pratincoles to settle, especially those in salty soils that inhibits plant growth. Not suitable crops are those which are too dense for pratincoles to use as colony sites at the time of settlement. *Includes fallow land.

	Crop	Hectares
Suitable for pratincoles to settle		
(40% of total area)	Rice	32000
	Sunflower	83600
	Cotton	49400
	Legumes	14474
	Other uses *	19055
Not suitable for pratincoles to settle		
(60% of total area)	Cereals	100700
	Sunflower	167200
	Beetroot	13680
	Other crops	11598

Table 4.2 - Number of colonies in fallow and crops in 1989 and 1990.
Ct=Cotton, Sf=Sunflower, So=Sorghum,, Ba=Barren, Cp=Chickpea.

COLONIES IN FARMLAND							
	Fallows	Crops					
	Total	Ct	Sf	So	Ba	Cp	Total
1989	16	10	6	1	2	1	20
1990	9	14	5	0	2	1	22

2. Colonies in marshland

Tussock cover was the best determinant of the presence of a pratincole colony within marshland habitat. Tussock height was also included by the logistic regression analysis for 1990 (Table 4.4). In 1990, 75% of the cases were correctly classified, although when using the jack-knife method it dropped to 67%. Colonies were better classified than random points (86% and 60%, respectively). In 1992, 72.5% of the cases were correctly classified and when using the jack-knife method the same value was obtained. The method was equally good at classifying colonies and random points (70% and 75% respectively).

Colonies had lower tussock cover than random points (Table 4.5). Differences were significant in 1990 and 1992 (T-test, t=-2.66, df=34, $p<0.05$ and t=-3.58, df=38, $p<0.005$, respectively). Tussock height was not significantly different between colonies and random points in either year (t=-1.72, df=34, N.S. for 1990 and t=-1.93, df=33.44, N.S. for 1992). Grass cover and height, distance to the nearest road, distance to the nearest water resource and presence of fences, power lines or cattle were not entered by the logistic regression analysis. None of these variables differed between colonies and random points, except for presence of cattle: 67% of the colonies in marshland had cattle, whereas only 35% of the marshland fragments without colonies had cattle on them (Chi-square, X^2=4.38, df=1, n=44, p<0.05 for 1992).

3. Colonies in farmland

All colonies in farmland are included here, those in which there was a crop and those that were left as fallow for the season. At the time of settlement they all look similar: bare soil or slightly grown vegetation, either grass or the crop. Pratincoles do not select a specific crop, but crops finally develop in some of the colonies in agricultural land (Table 4.2).

Slope and distance to the nearest water resource were the two best determinants of the presence of a pratincole colony within farmland habitat, the latter improving the test very little (Table 4.6). In 1990 only the slope was entered by the logistic regression analysis. In this year, 70% of the cases were correctly classified (also 70% after using the jack-knife method), colonies being better classified than random points (97% and 33%, respectively). In 1992, an overall 72% of the cases (61% after the jack-knife method) were assigned to the correct group. Colonies were better classified than random points (80% and 66%, respectively).

Pratincoles chose breeding sites on flat fields which were close to water resources (Table 4.7). There were significantly more colonies in flat terrain than on slopes (Chi-square, X^2=9.78, df=1, n=55, p<0.005 for 1990 and X^2=17.54, df=1, n=87, p<0.00005 for 1992), and more colonies within 100 m of the nearest water resource than further than 100 m from it

(X^2=4.06, df=1, n=50, $p<0.05$ for 1990 and X^2=5.78, df=1, n=76, $p<0.05$ for 1992). Presence of fences and power lines were not significantly different.

Table 4.4 - Results of the logistic regression analysis of factors determining presence or absence of pratincole colonies (data from colonies in marshland).

	1990			1992		
	X^2	df	p	X^2	df	p
Goodness of Fit	35.73	33	N.S.	35.14	38	N.S.
Model Chi-square	14.32	2	<0.001	17.38	1	<0.0001
Improvement - tussock cover	7.21	1	<0.01	17.38	1	<0.0001
Improvement - tussock height	7.10	1	<0.01	------	---	---------

Table 4.5 - Mean vegetation cover and height (±se) in colonies in and random points in marshland in 1990 and 1992.

	1990		1992	
	Colonies	No colonies	Colonies	No colonies
Tussock cover	14.8±2.87 (21)	28.5±4.59 (15)	8.5±1.90 (20)	24.9±3.83 (20)
Tussock height	21.6±1.74 (21)	28.6±4.19 (15)	18.3±2.07 (20)	25.5±3.06 (20)
Grass cover	------	------	24.2±7.01 (20)	18.1±5.04 (20)
Grass height	------	------	6.3±1.25 (20)	11.7±4.74 (20)

Table 4.6 - Results of the logistic regression analysis of factors determining presence or absence of pratincole colonies (data from colonies in farmland).

	1990			1992		
	X^2	df	p	X^2	df	p
Goodness of Fit	49.99	48	N.S.	71.25	73	N.S.
Model Chi-square	8.53	1	<0.005	22.19	2	<0.0001
Improvement - slope	8.53	1	<0.005	17.64	1	<0.0001
Improvement - distance to water	----	--	------	4.54	1	<0.05

Table 4.7 - Inclination and distance to the nearest water resource in colonies and random points in farmland.

	Colony		No colony	
	1990	1992	1990	1992
Flat	29	33	16	27
Slope	1	2	9	25
<100 ms	23	30	11	25
>100 ms	6	5	10	16

4. Origin of the colonies located in farmland

Most of the colonies in farmland were once marshes, 86% and 97% for 1989 and 1990 respectively (Table 4.8). Only 3% of the colonies were on sites already transformed into crops in 1918.

Table 4.8 - Origin of colonies in farmland.

	1989	1990
Old marshes	72.2	78.8
Pastures near marshes	11.1	0.0
Farmland	2.8	3.0
Inland wetlands	13.9	18.1
N	36	33

DISCUSSION

Pratincoles prefer to choose marshland rather than farmland to settle in the study area, but many colonies are located in farmland. In certain years, as 1993, for circumstances described below, marshland is hardly used and most of the birds breed in farmland. Marshland is the natural breeding habitat of pratincoles in the area and most of the colonies located in farmland (97%) had been marshes before. In spite of the transformations, pratincoles keep breeding on them. Some of the farmland colonies have eventually been abandoned by the birds, especially those with less salty soils in which denser crops are obtained year after year and where there is no space left for cattle grazing or fallow lands.

Factors affecting colony-site selection in the study area

These are mainly inclination of the land and vegetation cover. Colonies are located in flat terrain with low vegetation cover. Hardly any colonies were found in places with vegetation cover over 15%. Other factors are particular to colonies in marshland or farmland.

In marshland there are more colonies where there are cattle present. Cattle have positive effects, such as keeping vegetation short or by encouraging dung-associated invertebrates. Von Haartman (1975) attributes the decline of some wader breeding populations in coastal areas of south-western Finland to changes in the vegetation composition and height after cattle had been taken from the area. Similarly, Sterbetz (1974) considered that the reduction in pratincole population in Hortobágy (Hungary) was associated with the reduction in cattle numbers and the tendency to keep them indoors. In the study area some colonies have not been used again after cattle have stopped grazing on them and vegetation has become too dense. Rankin (1979) found that lapwings nested in higher densities in places with more cow-pats and consequently more total invertebrate biomass. Also oystercatchers and redshanks had dung-associated invertebrates as main prey in their diet. No studies on cow dung invertebrate production and the relation with pratincole diet were carried out, but the main prey species found in faeces were not dung-associated (Chapter 5).

Another factor which affects settlement is soil humidity. This effect is stronger in marshland than in farmland as, in these, there are drainpipes to keep the soil dry and avoid flooding. Pratincoles lay their eggs on dry soil. Dolz *et al.* (1989) found that birds did not settle unless the level of the water table was more than 28 cm under the surface. Green (1988) found that settlement of common snipes *Gallinago gallinago* also depended on the water level. Although this was not measured in this study, it had a clear influence on pratincole settlement. Some marsh fragments in the process of being transformed into farmland are also drained, but most of them get partially flooded when it rains. In 1990, after a rainy winter, a few marsh fragments which had been colonies in previous years were still humid in springtime and they were not used by pratincoles. In 1993, after a long drought, it rained during the time of settlement (April to May). As a result of this, most marsh fragments were empty and instead, pratincoles nested on farmland where the water had not stayed.

Marsh size has been found to be important for some species, small fragments not being used by birds (Brown & Dinsmore 1986, Berg 1992). This was not measured here but pratincoles have been recorded nesting in marsh fragments as little as 0.9 ha.

In farmland, distance from the colony to the nearest water resource - and therefore to a food resource - was of relative importance. Food availability was studied in the Guadalquivir marshes region and it was slightly less in colonies in farmland than in colonies in marshland. Nevertheless, because of the patchy distribution of marsh fragments and reeds within the farmland, food availability seems to be adequate for breeding birds in both habitats (Chapter 5).

Land-use influences the availability of colony-sites for pratincoles. Changes in the crop grown in a colony from one year to another may oblige pratincoles to move, but they tend to stay nearby. Land-use is in its turn influenced by water availability and by crop prices and subsidies. In years with average rainfall, cotton (irrigated), sunflower (with or without irrigation) and rice, are the most common crops in the study area. In years with very low rainfall, rice is not sown and irrigation is not allowed. This was the case in 1993. Sunflower was widely used by farmers (also because it was subsided by the European Community) but crops were very poor. These and fallow lands (mostly rice fields), were widely used by pratincoles to breed.

In Chapter 7 I will discuss why pratincoles breed in marshland or farmland, once information on food availability and breeding success has been presented.

B. NEST SITE SELECTION

METHODS

Locating nests was described in Chapter 1.

1. Marshland

122 nests found in marshland were assigned to one of the following categories:

Nest surrounded by a cow pat
Nest on a cow pat
Nest at base of a tussock
Nest on a hoof print
Nest on flattened grass
Nest on dry mud.

In 1992 the following variables were measured in a 10 m radius around 35 nests and 37 random control points: vegetation cover and height, distance and height of the nearest tussock, number of hoof prints and number of cow pats. Only nests in colonies in marshland where there were or had been cattle were used to take these data.

2. Farmland

Data taken from marshland nests are not relevant in farmland as cattle do not graze in it and vegetation characteristics are very different. Instead, location of nests on plant rows or between rows was recorded. A nest was considered to be "on a row" if the whole nest was included in a band ten centimetres wide at either side of the plant row. Distance between rows was 95 cm. All data were taken from the farmland colony.

RESULTS

1. Marshland

Most of the 122 nests in marshland were located on dry mud (Table 4.9). When testing if pratincoles select denser or less covered areas with higher or lower vegetation, near to a tussock, in areas where hoof prints and cow pats were more or less abundant, no significant differences were obtained (Table 4.10, see page 59).

2. Farmland

Pratincoles placed their nests on rows more than between them ($X^2=45.228$, df=1, n=49, $p<0.001$). There were 30 nests on rows (10 expected) and 19 between them (39 expected). The expected number of nests was calculated taking into account that only 20 cm out of 95 are "on rows", and the remaining 75 cm are "between rows". This selection occurs throughout the laying period (Table 4.11).

Table 4.9 - Percentage of nests from colonies in marshland in the different categories considered.

Nest category	Percentage
Nest surrounded by a cow pat	5.7
Nest on a cow pat	6.5
Nest at base of a tussock	7.3
Nest on a hoof print	1.7
Nest on flattened grass	0.8
Nest on dry mud	77.9

Table 4.11 - Observed number of nests on rows and between rows during the laying period. It has to be taken into account that "rows" are 21.05% of the total colony area and "between rows" are 78.94%.

	26 April-30 May	1 May-5 May	6 May-10 May	11 May-15 May
On rows	3 (50%)	4 (57%)	10 (59%)	16 (84%)
Between rows	3 (50%)	3 (43%)	7 (41%)	3 (16%)

Table 4.10 - Mean value (±se) of the different variables measured in a 10 m radius around 35 nests and 37 random control points in colonies in marshland.

VARIABLES	NESTS (35)	RANDOM POINTS (37)
Tussock cover (%)	8.50 ±1.34	6.27±0.96
Tussock height (cm)	13.48±1.30	13.39±1.07
Grass cover (%)	9.13±1.54	7.91±0.96
Grass height (cm)	7.59±0.79	8.06±0.78
Distance to nearest tussock (cm)	346.8±86.60	293.1±59.23
Height nearest tussock (cm)	24.46 ±1.66	24.86±1.46
Number of hoof prints	89.03±22.83	111.89±27.04
Number of cow-pats	10.91±1.59	10.89±1.65

DISCUSSION

1. Marshland

Different wader species use cow dung as nest-sites (Rankin 1979). He suggested that the main factor for dry cow pats to be used as nests was the ease of scraping them. Also egg and chick camouflage could be important in the case of the lapwing. Pratincole eggs are well camouflaged on the soil and predation on them is very low (Chapter 6). Valverde (1960) and Sterbetz (1974) suggested that cow dung gives a certain thermal buffering to pratincole eggs laid on them. Sterbetz also suggested that it was safer to nest on cow pats as protection against heavy rains and flooding. Availability of cow pats is high and pratincoles are not selecting them to lay their eggs. They are also not nesting in areas where cow pat density is higher as occurred with lapwings (Rankin 1979). The same is the case for nests on hoof prints or those placed by a tussock.

None of the variables chosen were relevant, as nests sites and random points had similar values for all of them. Vegetation cover has been found to be important for other ground nesting species such as common terns (Blockpoel 1978) and kelp gull *Larus dominicanus* (Burger & Gochfeld 1981). In both those studies nests were placed in denser areas.

2. Farmland

There are more nests on rows than between them. Why do they select to nest on rows?.

1 - Selecting a plant to place the nest by it does not seem to be the case: in marshes they do not prefer to nest by tussocks. There are also colonies where there is no vegetation at all at laying.

2 - They may be "encouraged" to nest on rows as before starting breeding, there has already been machinery working on the field at least twice, and the rows may be in better condition than the space between them. This may not always be the case. In the study farmland colonies there was time enough for the earth to settle again and, to the human eye, it did not look different. There are also observations of nests laid in recently ploughed fields on very uneven ground.

3 - There may exist a process of learning. Birds may have learnt that, by laying their eggs by the small plants, chances of not losing them are very much higher compared to eggs laid in nests between rows.

CHAPTER 5

PRATINCOLE FEEDING ECOLOGY

INTRODUCTION

Collared pratincoles feed mainly on insects captured in the air though they can also capture prey on the ground or "leap over the prey" (Reynolds 1977). The latter has also been described in oriental pratincoles (Pierce 1978). These two methods are used both in and outside colonies (meadows, ploughed fields, rice fields being flooded or levelled) and throughout the time they spend in the area. But they mainly forage in the air (it is common to see them forming flocks) and it is to this method I shall be referring from now on.

There are no studies on the feeding ecology of this species. Some results of examination of adult stomach contents are gathered in the publications of Sterbetz (1974) and Glutz *et al.* (1977), but up to now nothing has been done on chick diet (Cramp & Simmons 1983). The same is the case for pratincole feeding activity and for quantitative information on food availability in the species' feeding and nesting grounds.

A reduced availability of food during the breeding period, from egg formation to chick fledging, may affect the breeding performance of aerial insectivores (Bryant 1975). Agricultural procedures may reduce the amount of food available for bird species nesting in or near fields as shown by Potts (1978) for grey partridge *Perdix perdix* and suggested by Uhlig (1989) for collared pratincoles. Also weather conditions can alter the birds' feeding activity and reduce food availability (Turner 1983). This affects in turn the number of chick feeds (Lack & Lack 1951, Turner 1984), chick growth and survival (Lack & Lack 1951, Rheinwald 1971, Beintema & Visser 1989).

In this chapter I examine different aspects of the feeding ecology of collared pratincoles in the study area. First of all I consider the use of the available habitats for feeding and food availability in them. Second, data on chicks' diets and adult feeding activity are presented. This information will be essential to understand the patterns of habitat use to form the colonies (Chapter 4) and chick performance (Chapter 6).

METHODS

1. Feeding areas

A transect (width range 50 to 500m) which included different types of habitats : dry marshland (38.45 ha), reeds plus shallow waters (36.25 ha), areas with mixed vegetation of marsh and meadows (13.27 ha) and crops (143.37 ha of cereals and 77.25 ha of other crops) was established in 1992. This habitat mix is typical of the region as a whole. The transect was travelled every fourth day during the breeding season between 12.00 and 15.00 hours, noting the number of pratincoles feeding in each type of habitat. This time of the day was chosen as by observation in previous years it was known that many pratincoles are feeding at that time. The area of the different habitats included in the transect was calculated, giving the number of birds per hectare in each habitat.

The transect was travelled twice in the same day 19 days out of 25. These results were used to check data consistency within a day. Numbers on the first trip highly correlated with numbers on the return trip (Fig. 5.1, $r^2=73.1\%$, $n=19$, $p<0.001$.).

2. Feeding activity

When testing for temporal variations in feeding activity three periods are considered: incubation (21st of April to 21st of May), chick rearing (21st May to 26th June) and post-breeding (27th of June on). Data on date, formation of feeding flocks, wind speed and cloudiness when travelling the transects were recorded. A flock was considered to be when there were more than 50 individuals feeding within 500 metres. Wind speed was roughly measured in a scale of 3 points: 1.Nothing moves, 2.Breeze, 3.Windy. Cloudiness was measured in a similar way: 1.Clear sky, 2.<50% white clouds, 3.>50% white clouds, 0% grey clouds, 4.Up to 50% grey clouds and 5.>50% grey clouds. Rainfall data from the nearest weather station were used and transect days were assigned to 1. or 0. if it rained or not respectively. Rainfall one day after the transect was also used as an indication of general atmospheric condition. In no case did rain occur one day before study days.

The number of birds feeding at different times of the day during the incubation period in a feeding area (reeds and shallow waters) was also recorded. At least two readings were taken per hour from 08.00 to 22.00 in the period from 26 April to 14 May. These were only taken during the incubation period as, as will be discussed later, after the eggs have hatched pratincoles feed mainly in a restricted area near the colonies, and afterwards numbers in the study area start to decline.

3. Diet

Pratincoles feed mainly on insects captured in the air and it is difficult to see what they are feeding on. Collecting bird stomachs for diet analyses was not considered appropriate. The few stomach analyses presented here are from birds found dead. One adult was hit by a car and another killed by a poacher. A chick killed by a dog was also obtained. As alternative methods to study diet, flushing the digestive tract and faeces collection were considered. For adults neither was adequate as it was not possible to capture large numbers of birds. Very rarely adults were observed producing a dropping. Jenni *et al.* (1990) studied the efficiency of these two methods and found that both produced biased results for certain prey types. Neither method was clearly preferable to the other. Faecal analysis was chosen to avoid any harmful effect that flushing could have on the birds.

When rearing chicks, adults tend to feed flying over the colony or nearby and take the prey to the chicks. Chicks are fed by their parents all through their development, although they may peck at insects on the ground. This seems to be only occasional and chicks depend on food brought by adults. Adults bring the prey in the beak and chicks take it from there. It was not possible to see what chicks were being fed on and, therefore size of prey could not be recorded. When not being fed, chicks tend to hide. Faeces were collected from chicks when handling them for ringing and measuring. Forty-four and sixteen excrements were collected in 1992 and 1993 respectively. Only data from 1992 are used to make habitat and age comparisons. Also several experiments were carried out with chicks in captivity. These chicks were fed with a mixture of bird food, dog food, fish meal, vitamins, proteins and minerals. During the experiments chicks were fed with a known amount of a particular invertebrate species and droppings were collected over a period of 5 to 8 hours. These droppings were analysed under a binocular microscope to find out what insect fragments were useful to identify prey in droppings collected from chicks in the wild. A reference collection from the study sites was used to help with the identification of fragments. Only qualitative data are given as not all the remains came through in the droppings and numbers of droppings produced depended on the composition of the maintenance diet. To test for differences in diet with chick age three groups of chicks were classified by wing length.

Medium size individuals of the most common taxa found in faeces were dried to constant weight in an oven. Where possible only species which pratincoles are known to feed on were used.

4. Food availability

In 1990 and 1992 food availability was measured using pitfalls. The former year 4 pit-falls (plastic cups, 13 cm diameter x 25 cm deep) were set in a colony in marshland and a colony in a cotton field. In 1992 8 pit-falls (plastic cups, 7.5 cm diameter x 10 cm deep) and sticky bands (one rectangle 40 x 9 cm set 150 cm high) were set in two colonies in marshland (one within an agricultural area and the other one in a traditional colony in the National Park of Doñana which was eventually not formed this year), a piece of marshland which was not used as a colony but was frequently used as a feeding area, a feeding area with reeds and shallow water, and a colony in a cotton field. Pitfalls were collected every 8th day and sticky traps every 12th day. Pitfalls were used without any fixing liquid as temperatures are too high and evaporation occurred very quickly. Sticky traps were all oriented in the same direction, avoiding the sun in the peak sunny hours. The sticky-traps trapped arthropods within the range 0.1 to 0.5 cm, and remained sticky for over twelve days.

Arthropods were classified to Order in sticky traps and pit-falls. For the latter, Coleoptera and Hemiptera were classified to Family level. Richness (number of taxa considered) and abundance (total number of individuals) were calculated. Ants are not included in any of the calculations as some were capable of climbing out of the traps. The Berger-Parker Index was used to calculate diversity: d=Nmax/N, where Nmax is the maximum number obtained for a particular taxon and N is the total number of individuals. The inverse is usually adopted as the index (Magurran 1989). Higher values indicate higher diversity and low dominance of any particular taxon.

Capture rate for each taxon (total number of individuals/day of trapping) was calculated to test for temporal and habitat differences. The variables 'total number of arthropods', 'total number of Coleoptera' (pit-falls only) and 'total number of Hemiptera' (sticky-traps only) were used for this purpose. Numbers of Coleoptera and Hemiptera were used as they seem to be important taxa in pratincole diet. Also these taxa were represented all through the season in numbers high enough to allow statistical analysis. Interactions of habitat and date were analysed with two-way ANOVA. Where appropriate, a one-way analysis of variance was carried out for each variable. For temporal variation comparisons were made between incubation, chick rearing and post-breeding periods of the pratincole breeding cycle.

RESULTS

1. Feeding areas

Firstly interaction of habitat type and date within the breeding season affecting pratincoles feeding density (birds/ha) were tested with a two-way ANOVA. No interaction was found (F=0.68, df=8,100, N.S.) but there were significant differences in the density of individuals feeding in different habitats. Less individuals used non-cereal crops (beetroot, cotton, sunflower) than other habitats (Table 5.1, two-way ANOVA, F=11.08, df=4,100, p<0.0001, Tukey test, $p<0.05$). Cereals had the highest percentage of individuals (not density) feeding in them, followed by marsh and reed habitats.

Table 5.1 - Mean density (birds/ha) (±se) and percentage of pratincoles feeding in different habitats.

	Marsh	Reeds	Marsh + meadow	Cereals	Other crops
Density	53.2±16.11	52.2±16.94	49.4±17.74	35.7±8.21	1.6±0.67
Percentage	20.8%	19.2%	6.7%	52.0%	1.3%
N	25	25	25	25	25

2. Feeding activity

2.1 Temporal (seasonal-daily)

The two-way ANOVA also detected a significant difference of density of feeding birds at different times during the breeding season ($F=5.38$, $df=2,100$, $p<0.01$). Differences are significant between the incubation period and the chick rearing period, density being lower in the latter (Table 5.2, LSD test, $p<0.05$). Also the number of flocks formed followed this pattern (Fig. 5.2), decreasing during the chick-rearing period. Big groups (more than 100 individuals) were only seen during the first and last period.

Table 5.2 - Mean pratincole feeding density at different periods during the breeding season.

	Incubation	Chick-rearing	Post-breeding
Mean	75.3	14.4	25.9
se	16.98	2.87	6.23
N	40	45	40

Daily feeding activity increased in the morning coming to a peak in the afternoon and declining again in the evening (Fig. 5.3). It is subject to prey availability and so, presumably depends on insect activity. There can therefore be a big variability in the feeding activity patterns depending on availability of prey. In specific places it is common to see pratincoles feeding at dawn and dusk.

2.2 Weather

Only effects of some weather parameters on feeding density will be given. Number of days with and without flocks are too few for statistical analysis. Although the total number of pratincoles feeding are related here to weather parameters, I am aware that weather is affecting insect availability and therefore indirectly affecting pratincole feeding activity.

2.2.1 Wind

There is a significant difference in feeding density on windy days and calm days (Table 5.3, oneway ANOVA, F=3.89, df=2,122, $p<0.05$). Hardly any birds were recorded on days with strong wind. The same tendency is shown with flock formation. No flocks were formed on days with very strong wind and on only one out of four windy days was there flock formation.

Wind also affects the height at which pratincoles feed. The stronger the wind the higher the number of individuals feeding under 5 metres (Table 5.3, Kruskall-Wallis, $X^2=23.38$, $n=125$, $p<0.0001$).

Table 5.3. - Mean pratincole feeding density and mean A/B ratio in days with different wind speed. A=feeding density under 5 metres, B=feeding density over that height.

	Nothing moves	Breeze	Windy
Feeding density	47.3±10.38	50.1±12.21	19.3±6.01
A/B Ratio	0.6±0.14	2.6±1.42	11.8±5.70
N	25	55	45

2.2.2 Cloudiness

No significant differences were found in foraging activity on days with more or less cloud cover (Table 5.4, Kruskall-Wallis, $X^2=0.83$, $n=125$, N.S.), although clear days had the highest number of individuals foraging. On days with thick cloud cover, birds flew lower than on clearer days (Table 5.4, Kruskall-Wallis, $X^2=11.70$, $n=125$, $p<0.005$).

Table 5.4 - Mean pratincole feeding density and A/B ratio in days with different cloud cover. A=feeding density under 5 metres, B=feeding density over that height.

	Clear sky	Partially cloudy	Cloudy
Feeding density	46.5±9.50	25.5±6.82	27.1±10.34
A/B ratio	3.1±1.16	0.8±1.15	17.4±10.1
N	75	25	25

2.2.3 Rainfall

Feeding density on days with rain was not significantly different from that on days without rain (Table 5.5, Mann-Whitney, U=744.0, Z=-0.62, n=125, N.S.). On rainy days birds flew lower than on days without rain (Table 5.5, Mann-Whitney U=315.5, Z=-3.94, n=125, p<0.0005).

When considering feeding activity in relation to rainfall one day after the transect was travelled, no significant differences were found (Table 5.5, Mann-Whitney, U=1229.5, Z=-0.13, n=125, N.S.). Differences in feeding height were not significant in this case either (Table 5.5, Mann-Whitney, U=952.0, Z=-1.87, n=125, N.S.).

Table 5.5-Mean pratincole feeding density and mean A/B ratio in days with and without rain, on sampling days and on the next days. A=feeding density under 5 metres, B=feeding density over that height.

	No rain	Rain
Sampling days		
Feeding density	38.9±6.75	35.0±16.75
A/B Ratio	2.5±0.80	27.5±16.5
N	110	15
One day after sampling		
Feeding density	40.0±7.37	32.0±10.42
A/B Ratio	3.0±0.94	15.3±10.12
N	100	25

3. Diet

3.1 Feeding experiment

Most of the species chosen for the feeding experiment proved to be very useful when identifying fragments from droppings collected from chicks in nature. Unfortunately, only in one case all fragments that came out did so before the end of the experiment. The first ones tend to appear more than one hour after captive chicks had ingested them. In two cases nothing came out in the 270 minutes observation. There was no obvious relation between time for the first fragments to come out and size or hardness of the prey (Table 5.6).

When fed on dragonflies, a total of 135 minutes were necessary for all pieces that came out to do so. Forty three droppings without remains were collected afterwards (Table 5.7). For all body parts, some fragments were never found in faeces.

3.2 Faeces analysis

In 1992 the most frequently represented taxa in chick faeces from marshland and farmland were Hemiptera and Coleoptera (Table 5.8). These two taxa were the only ones present in more than 50% of the faeces. Odonata was the next most represented taxon in farmland (29%) but not in marshland (8%). Ants and Diptera were similarly represented in both habitats. The other taxa have been found sporadically. In 1993 Coleoptera was the predominant taxon whereas there were very few Hemiptera present (Table 5.8). A different digestibility of prey could result in certain taxa being less represented in faeces than in the diet. Table 5.9 shows the dry weight of the taxa most encountered in faeces.

Table 5.6 - Taxa used for feeding experiments, time of faeces collection and time for first fragments to come out in the faeces.

Taxon group	Items	Minutes observation	First fragments
O.Odonata	1	463	37
O.Orthoptera			
F.Acrididae	1	472	146
O.Hemiptera			
F.Scutelleridae	2	270	103
F.Pentatomidae	2	270	180
O.Diptera			
Mosquitoes	15	270	41
Flies	3	270	240
O.Hymenoptera			
Ants	10	270	240
O.Coleoptera			
F.Carabidae	2	270	60
F.Curculionidae	2	270	--
F.Cicindelidae	2	270	95
O.Opiliones	2	270	--

Table 5.7 - Different dragonfly fragments encountered in the faeces and time (min.) taken to come out since the beginning.

Minutes	Number of faeces	Tibia	Femur	Leg claws	Wing fragments	Mandible fragments	Body fragments
37	3	--	--	--	--	--	--
72	1	1	--	2	+	--	--
80	3	1	--	--	+	+	+
97	3	--	--	--	--	--	+
103	2	--	--	2	--	--	+
111	2	1	1	2	+	+	+
127	3	--	--	--	--	--	+
135	4	1	--	2	--	--	--
463	43	--	--	--	--	--	--

Table 5.8 - Percentage of chick's faeces from colonies in marshland and farmland in which remains of different taxa were present.

	1992		1993	
	Marshland	Farmland	Marshland	Farmland
Hemiptera (Total)	72	53	17	0
Cereal pests	64	53	0	0
Others	12	0	17	0
Himenoptera (Ants)	24	23	34	40
Dermaptera	12	6	17	0
Orhtoptera				
F. Acrididae	12	0	0	0
Odonata	8	29	17	0
Diptera	16	18	34	30
Coleoptera (Total)	80	59	100	60
Scarabeidae	24	0	17	0
Carabeidae	8	12	50	0
Curculionidae	20	6	0	0
Others	64	53	100	60
Acarina	4	0	0	0
Psocoptera	0	0	17	0
Isopoda	0	0	0	17
N	25	17	6	10

Table 5.9 - Dry weight (g) of different taxa encountered in pratincole faeces.

Hemiptera		
Aelia sp.	0.043±0.006	11
Eurygaster sp.	0.074±0.017	11
Himenoptera (Ants)	$0.001 \pm 5.7 \times 10^{-5}$	14
Odonata	0.052±0.015	10
Coleoptera	0.057±0.024	26

There was no difference between habitats (marshland or farmland) in the number of taxa found in the droppings (Fig. 5.4, Chi-square, X^2=2.22, n=42, df=2, N.S.), although there was a higher percentage of droppings from marshes with high numbers of taxa in them.

The diet was similar at different stages of development, the same taxa being important at the three stages considered (Table 5.10). The diet of recently hatched chicks included hard insects. No difference was found between chick age and number of taxa present in the droppings (Fig. 5.5, Chi-square, X^2=2.67, n=42, df=2, N.S.).

The result of the analysis of three droppings from adults and two stomach contents from dead adults are shown in Table 5.11. The most important taxa are the same as for chicks, although data are too scarce to draw any conclusion.

4. Food availability

4.1 Pit-falls

Total numbers of individuals of different taxa trapped in pit-falls in 1989 and 1992 are shown in Tables 5.12 and 5.13. Coleoptera was amongst the most trapped taxa in all habitats in both years. Numbers of Isopoda (wood lice), Araneae (spiders) and Acarina (ticks and mites) were usually high in all habitats. Diptera were trapped in high numbers in reeds and in the farmland colony in 1989 (but not in 1992). Orthoptera was the most trapped taxon in the marsh colony in 1989. Tables 5.14 and 5.15 show the abundance, richness and the Berger-Parker Index for each habitat in 1989 and 1992 respectively. Comparison between years is not possible as number and size of traps were different. Species richness was similar in the habitats considered although in 1992 richness in the farmland colony was lower than in the rest of the habitats. Abundance differed among habitats, marshes with colonies being the places with higher numbers of arthropods (Doñana and marsh-colony). The reed area was next followed by the marsh no-colony and finally the colony in farmland. The same pattern occurred in 1989, with nearly twice as many individuals in the colony in marshland as in the colony in farmland. In 1992 diversity was highest in Doñana followed by the colony in farmland and the reed area. The marshland without a colony and the colony in farmland were the least diverse (higher dominance of a certain taxon). The pattern between the colony in marshland and the colony in farmland for 1989 is similar to the one described for 1992.

Capture rate was analysed for the total number of arthropods and for the total number of Coleoptera. For the former, neither habitat nor date on their own had a significant effect on capture rate. The highest capture rate was recorded in marshes and the lowest in the crop (Tables 5.14 and 5.15, two-way ANOVA, F=1.55, df=1,18, N.S. for 1989 and F=1.72, df=4,50, N.S. for 1992). The temporal pattern is a decline at the end of the season for both but differences were not significant (Table 5.16, F=3.51, df=2,18, N.S. for 1989 and F=2.52, df=2, 50, N.S. for 1992).

When considering capture rate of Coleoptera, neither habitat nor date had a significant effect in 1989 (Tables 5.14 and 5.16, two-way ANOVA, F=0.43, df=1,18, N.S. and F=2.85, df=2,18, N.S. respectively), but both of them did in 1992. Here, capture rate was higher in the marshland colony and in Doñana than in the other habitats, and this difference was significant (Table 5.15, two-way ANOVA, F=15.26, df=4,50, p<0.001, LSD<0.05). Also higher capture rates were obtained earlier in the season (Table 5.16, two-way ANOVA, F=5.32, df=2,50, p<0.01, LSD <0.05). There was no interaction of date and habitat in 1992 (F= 1.40, df=8,50, N.S.).

Table 5.10 - Proportion of faeces from chicks at different stage of development in which remains from different taxa were present. Age after wing length (mm).

	21-52	53-90	>90
Hemiptera (Total)	69	67	57
Cereal pests	69	67	43
Others	0	0	21
Himenoptera (Ants)	31	20	21
Dermaptera	8	13	7
Orthoptera			
F Acrididae	8	7	7
Odonata	15	7	29
Diptera	31	7	14
Coleoptera (Total)	62	80	71
Scarabeidae	8	27	7
Carabeidae	15	7	7
Curculionidae	8	13	21
Others	54	67	57
Acarina	0	0	7
N	13	15	14

Table 5.11 - Presence / absence of invertebrate taxa in adults faeces and stomachs.

	Faeces	Stomachs	
		Marsh	Rice field
Hemiptera			
Cereal pests	1	-	+
Others	0	+	-
Himenoptera (Ants)	1	+	-
Dermaptera	2	+	-
Orthoptera			
F Acrididae	0	-	-
Odonata	0	+	-
Diptera	1	+	-
Coleoptera			
Scarabeidae	1	+	-
Carabeidae	1	-	-
Curculionidae	1	-	+
Others	3	-	+
Acarina	0	-	-
N	3	1	1

Table 5.12 - Number of individuals from different taxa obtained in pit-falls in 1989.

TAXON	MARSHLAND	FARMLAND
Chilopoda	2	0
Isopoda	68	0
Acarina	63	2
Araneae	75	25
Orthoptera	102	45
Diptera	62	116
Himenoptera, no ants	25	1
Hemiptera (total)	2	7
Miridae	0	2
Reduviidae	2	0
Aphids	0	5
Coleoptera (total)	66	88
Estaphilenidae	1	1
Cicindelidae	6	0
Elateridae	0	31
Cleridae	0	16
Desrmestidae	0	25
Scarabeidae	1	2
Carabeidae	56	10
Cantaroidae	0	1
Coleoptera larvae	2	2
Non-identified	4	0

Table 5.13 - Number of individuals from different taxa obtained in pit-falls in 1992.

Taxon	Marshland colony	Reeds	Marsh no colony	Farmland colony	Doñana
Chilopoda	18	16	9	5	50
Isopoda	31	34	9	6	73
Acarina	157	4	8	2	30
Araneae	45	79	49	13	91
Orthoptera	6	1	1		10
Embioptera				2	
Mantidae	3				
Machilidae	1		1		
Diptera		57	6		2
Himenoptera, no ants	1			1	
Dermaptera	1	1			1
Hemiptera (total)	116	4	7	37	23
Miridae	1		5		
Reduviidae	18		1		
Lygaeidae	73				23
Aphids		3	1	37	
Hemiptera inmatures	24	1			
Coleoptera (total)	159	44	30	27	188
Estaphilenidae		3		1	10
Cicindelidae	46	1			19
Desrmestidae					1
Scarabeidae			1	1	
Carabeidae	86	24	13	11	94
Curculionidae		3	1	1	47
Tenebrionidae	20	8	5	11	7
Bupestridae					9
Ptinidae		2	1		
Histeridae					1
Chrysomelidae	3				
Coleoptera larvae	7		9	2	
Non-identified					1

Table 5.14 - Mean capture rate (±se), abundance (N, total number of individuals), richness (S, number of taxa) and Berger-Parker index (1/d) from pit-falls in a marshland colony and a farmland colony in 1989. Capture rate=total individuals captured/day of trapping. n=number of times the trap was emptied.

	Marshland	Farmland
N	470	282
S	13	16
1/d	4.6	2.4
Arthropods capture rate	5.3±0.70 (17)	3.3±1.06 (7)
Coleoptera capture rate	0.7±0.18 (17)	0.9±0.42 (7)

Table 5.15 - Mean capture rate (±se), abundance (N, total number of individuals), richness (S, number of taxa) and Berger-Parker index (1/d) from pit-falls in 1992. Capture rate=total individuals captured/day of trapping. n=number of times the trap was emptied.

	Marshland colony	Reeds	Marsh no colony	Farmland colony	Doñana
N	538	240	120	94	469
S	17	16	16	12	16
1/d	3.4	3.0	2.5	2.5	5.0
Arthropods capture rate	6.1±1.03 (14)	4.7±0.84 (14)	5.4±1.59 (14)	2.4±0.88 (14)	5.6±1.57 (9)
Coleoptera capture rate	1.7±0.33 (14)	0.5±0.11 (14)	0.3±0.12 (14)	0.3±0.06 (14)	1.8±0.35 (9)

Table 5.16 - Mean capture rate (±se) at different times during the breeding period in pit-falls in 1989 and 1992. Capture rate=total individuals captured/day of trapping.

	Incubation	Chick-rearing	Post-breeding
1989			
Arthropods capture rate	3.5±1.10	6.6±0.80	3.4±0.93
Coleoptera capture rate	0.9±0.30	1.0±0.31	0.2±0.11
N	7	10	7
1992			
Arhtropods capture rate	6.4±1.48	4.9±0.77	3.2±0.59
Coleoptera capture rate	1.08±0.32	0.99±0.18	0.44±0.14
N	15	31	19

4.2 Sticky-traps

Numbers of individuals from each taxon trapped in each habitat are shown in Table 5.17. Hemiptera and Diptera were the most abundant taxa overall. In reeds there was an explosion of the Psocoptera population and this is the most trapped taxon in this habitat. Abundance, richness and the Berger-Parker Index are given in Table 5.18. Species richness was similar in all the habitats. Abundance was by far the highest in the reeds (aerial feeding area) with 1678 individuals, followed by the piece of marsh without a colony (but used frequently for aerial feeding) with 584 individuals. The lowest number was again obtained in the farmland colony. The abundance in Doñana was close to that of the farmland colony. Effectively, there is a significant difference in the capture rate between reeds and the marsh colony, farmland colony and Doñana (see below). Reeds had the highest diversity along with Doñana and closely followed by the farmland colony. Both marshland fragments (colony and no colony) had low scores of diversity and, therefore, higher dominance of a certain taxon (Diptera and Hemiptera).

Capture rate was higher in areas with reeds than elsewhere when considering the total number of arthropods (Table 5.18, one-way ANOVA, F=7.30, df=4,15, p<0.005). Capture rate of Hemiptera was more even among the different habitats and no significant differences were obtained (Table 5.18, one-way ANOVA, F=1.73, df=4,15, N.S.). There was no significant difference in the total number of arthropods, (Table 5.19, one-way ANOVA, F=0.22, df=2,30, N.S.) or number of Hemiptera (F=2.99, df=2,30, N.S.) trapped at different times within the breeding season.

Table 5.17 - Number of individuals from different taxa obtained in sticky-traps in 1992.

	Marshland colony	Reeds	Marsh no colony	Farmland colony	Doñana
Diptera	139	584	174	47	96
Himenoptera	37	136	49	56	86
Hemiptera	219	249	306	99	48
Coleoptera	14	12	11	6	4
Thysanoptera	5	10	5	10	5
Dermaptera	0	2	0	0	0
Psocoptera	12	656	33	7	0
Aracnida	3	29	6	7	6

Table 5.18 - Mean capture rate (±se), abundance (N, total number of individuals), richness (S, number of taxa) and Berger-Parker index (1/d) from sticky traps in 1992. Capture rate= total individuals captured/day of trapping.

	Marshland colony	Reeds	Marsh no colony	Farmland colony	Doñana
N	429	1678	584	232	245
S	7	8	7	7	6
1/d	2.0	2.6	1.9	2.3	2.6
Arthropods capture rate	4.7±1.31	12.1±2.65	6.7±1.15	2.4±0.61	3.0±0.38
Hemiptera capture rate	2.3±1.11	2.8±1.34	3.5±0.94	1.1±0.35	0.6±0.41
N	4	4	4	4	4

Table 5.19 - Mean capture rate (±se) at different times during the breeding period in sticky traps in 1992. Capture rate=total individuals captured/day of trapping.

	Incubation	Chick-rearing	Post-breeding
Arthropods capture rate	5.9 ±1.26	7.6 ±3.19	5.8 ±1.42
Hemiptera capture rate	3.91±0.80	2.3 ±0.95	1.4 ±0.53
N	9	10	14

DISCUSSION

1. Feeding area and food availability

The study area is a patchwork of crops (mainly cotton, sunflower and cereals) and channels with fragments of marshland, reeds and shallow waters. Within these, pratincoles feed preferably over marshy areas and wetlands and they hardly use any crops, except for cereals. The results obtained from invertebrate sampling showed that capture rate in crops (cotton field) was invariably lower than in any other habitat. In sticky-traps numbers were also very low in Doñana National Park. This is a very fragile habitat highly dependent on water supply. The 1992 season was dry and there was hardly any water in the surroundings. Invertebrates trapped in sticky-traps seem to be more affected than those trapped in pit-falls and had a very low capture rate. A lack of water and food supply could be a reason for the colony which traditionally settles in the sampled area not forming this year. In the agricultural land water is kept artificially in channels and some reed habitats and food and water supply do not seem to be a problem for pratincoles. In the National Park of Doñana few birds nested in 1992 and 1993 (dry years) as compared to other years with average rainfall, whereas numbers were very high in 1990. The winter 1989/90 was exceptionally rainy and the park kept more water than usual and for a longer period, so probably food conditions were good for pratincoles. The population outside the park was more stable in these years (Calvo *et al.* 1993, Appendix 2). Although the agricultural areas seem to keep conditions for insects more even throughout the years than natural areas, a fluctuation in insect production associated with weather conditions undoubtedly occurs every year and depending on each insect species (Williams 1951).

In general, reeds and marshland (except Doñana for reasons explained above) were the habitats where ground and flying invertebrates were more abundant. The sampling site at the marshland without a colony had high capture rates and, although there were no birds nesting in it, it was frequently used as a feeding place. Reeds and marshes, together with cereals, were also the most used habitats for feeding. Cereals seem to carry more insects than other crops. Pratincoles feed very frequently on species which are pests in these crops: *Aelia rostrata*, *Aelia germani* (Fam. *Pentatomidae*), *Eurygaster austriacus* and *Eurygaster maura* (Fam. *Scutelleridae*). Remains from these species are very frequent in their faeces.

Invertebrates were sampled from the end of April to the end of July. There is a slight decrease in capture rate at the end of the season but differences were generally not significant (significantly less Coleoptera were captured in the post-breeding season in pit-falls in 1992).

2. Feeding activity

The number of individuals recorded feeding in the air when travelling the transect was highest during the incubation period, decreasing to a minimum during the chick-rearing period and increasing again afterwards. This decrease is probably due to pratincoles staying closer to their colonies (which were outside the transect) once the eggs have hatched. They feed near the colonies and take the food to their chicks. Numbers do not rise after breeding as some birds have already left the area.

Pratincole feeding time during the day has traditionally been considered to be at dawn and at dusk (Valverde 1960, Cramp & Simmons 1983). The pattern of daily activity obtained here was an increase in the morning, reaching a peak in the afternoon and declining in the evening. In other areas crepuscular activity has been observed. Undoubtedly, feeding activity is subject to insect prey activity and this, in turn, depends on the vegetation and soil substrate and several atmospheric parameters. Food availability in areas with different vegetation will be discussed below.

Light and temperature are two factors limiting insect flight and activity. Under a minimum light intensity and temperature some insect species cannot fly (Chapman 1982), big insects needing longer to warm up than small ones (Johnson 1969). The latter says that, although not a rigid rule, there are more insects in the air the warmer it gets. With rising temperatures upward air currents carry insects higher up. Effectively, in days when other factors as rainfall or wind are not affecting the birds (see below), pratincoles feed at higher levels as the warming progresses. Gustafson *et al.* (1977) found that swifts *Apus apus* flew at higher altitudes in clear weather. My results fit with this model in which activity is low early in the morning, increasing as it warms up (flying height increases as well) and declining when temperature drops. This pattern of activity has been observed in other locations in the study area. At dawn and dusk many insects can be carried in rising currents formed by convective movements of the air. Swifts and nightjars *Caprimulgus* sp. feed widely on these insects (Ross 1973). In places with hot day temperatures some insect species are not active during the peak hot hours but at dusk (Beck 1971, Ross 1973). Pratincoles feeding at dawn and dusk are also a common sight in the area, usually in specific places and for a certain period of time, as if birds were exploiting a temporary source of food. Some insect species are basically nocturnal and would not fly with day-light (Chapman 1982). Although pratincoles do not usually feed at night, they have been observed feeding by artificial light (M. Máñez, *pers.comm.*) and sporadically with full moon (Valverde 1960).

Rainfall has also an influence on insect activity. Intensity of rainfall is more important than the actual amount of rain. A rain storm can impede insects from taking off or wash them out of the air (Freeman 1945, Johnson 1969). Rainfall was scarce during pratincoles breeding seasons in the study area and mainly of stormy character, which probably influenced food availability for pratincoles at a given time, although the number of individuals feeding in the air on rainy days was similar to that on days without rain.

The effect of changing pressures on insect activity is not well studied although there seems to be no doubt that it affects them (Johnson 1969). Cloudiness was used as an indicator of low pressure. Less pratincoles were recorded feeding on these days but differences were not significant.

Another factor which affects insect activity is wind speed. In general high wind speeds inhibit flight but light ones can stimulate it (Freeman 1945, Johnson 1969, Chapman 1982). This pattern of activity fits well with the feeding activity of pratincoles. Numbers of birds feeding on windy days were much lower and flocks were not formed on such days. Also flying height was affected, birds flying lower with stronger wind. On these days they frequently foraged by the method of "leaping over the prey".

Although each weather factor has been treated separately, it is a combination of all of them and some others (e.g. humidity, insect internal factors) at a given day which affects insect activity and, in turn, birds feeding activity. Also factors of individual birds should be considered (e.g. physiological condition, stage in the breeding cycle).

Although there are some feeding areas which are regularly used, collared pratincoles are also opportunistic birds in their feeding habits and they use alternative foraging strategies and areas. They can peck at invertebrates which are forced to come up to the soil surface when fields are flooded to sow rice or behind tractors ploughing a field (together with cattle egrets *Bubulcus ibis*). They also fly low above pool surfaces feeding on emergent insects or over fields where stubble has recently been burnt. The higher temperature creates ascendant air currents which carry insects in it. Sterbetz (1974) says that they follow cattle as there are insects associated with them and also because, when moving they make insects come out of the vegetation.

3. Diet

Chicks in my study area were fed mainly on Coleoptera and Hemiptera. These taxa were also amongst the most represented in both trapping methods. Most of the species are the same in faeces from chicks reared in marshland and farmland. There is a wide range of Coleoptera species in their diet, but there are mainly two species of Hemiptera: *Aelia* spp. and *Eurygaster* spp, both of which are pests in cereal crops. The same is the case for Diptera, for which a single non-identified species appears in most of the faeces with Diptera in them. Some of the ants present in the droppings were flying individuals but most of them were wingless. Chicks from both habitats seem to peck them from the ground. Ant remains are found in approximately the same percentage of droppings in marshland and farmland. Odonata and

Diptera are very abundant in the area during the chick rearing period, but adults do not seem to be widely feeding chicks on them. In 1993, due to the extreme dry conditions, hardly any cereals were grown in the area and the availability of Hemiptera was lower as pratincoles feed mainly on Hemiptera which are crop pests. Ground-living taxa like Chilopoda, Isopoda and Aranea are abundant in the marshland colonies but fragments were not found in the faeces in 1992 and only occasionally in 1993. The same occurs with the taxon Psocoptera. These were very abundant only in the reed feeding area and during one week in July. There is not much information on chick diet elsewhere and data on pratincole diet are mainly from adult stomach contents (Sterbetz 1974, Glutz *et al.* 1977, Cramp & Simmons 1983). Coleoptera, Orthoptera and Diptera are the main prey orders found in these. The few droppings and stomachs collected from adults in the study area contained the same species as the ones found in chick droppings.

4. Food availability and chick performance

With the information on feeding ecology presented in this chapter and the results obtained for chicks (Chapter 3) the effects of food availability on chick performance can be discussed.

A reduced food availability in farmland can cause a decrease in chick survival (Green 1984, Hill 1985), although sometimes it has been found that farmland presents better feeding conditions (Galbraith 1988a, van Impe 1988). In this area invertebrate capture rate was generally higher in the marshland colony than in the farmland colony, but differences were only significant for Coleoptera captured in pit-falls in 1992. Even if the overall invertebrate biomass is reduced by changes in land use, there still seems to be enough for pratincoles in agricultural areas.

There are two points to make when considering food availability in the study sites. Pit-falls in the farmland colony were laid within the cotton field, but at the edges of the field and by the irrigation channels grow wild vegetation where insect abundance is probably higher. Green (1984) found that grey and red-legged partridge chicks preferred to feed close to the edges of the fields where food (arthropods and seeds) was more abundant. Although pratincole chicks obtain their food mainly via adults, food availability for the latter is probably higher than obtained from pit-falls in the cotton field. Secondly, marsh fragments are patchily distributed within the agricultural area. Adults from marshland colonies forage in crops close to their colonies and adults from farmland colonies forage in nearby marshes. Altogether food available in the area of the farmland colony is probably not that different from that in the marshland colony and, in any case, enough for pratincoles. The data obtained on chick growth support this. Chicks from marshland and farmland colonies were fed the same number of times and their diet was similar. There was no difference in adult attendance in both habitats indicating that the effort to get food was not different. Adults spent less time with the brood the older the chicks. Growth was practically identical in both habitats and there was no evidence of chicks being short of food. The same was found by Baines (1990) for lapwings breeding on unimproved and improved farmland, although food resources were lower in the latter.

Weather can be a constraint for chick growth (Beintema & Visser 1989) through a reduced feeding activity of chicks or adults, or a reduced food availability (Koskimies 1950, Rheinwald 1971, Green 1984, Rands 1985). Although feeding activity was affected by bad weather conditions, these rarely occurred during the chick-rearing period and they were always of very short duration. Adults have hardly been seen brooding chicks during the day, except for chicks one or two days old. At night they brood even fledged chicks. I do not think weather in the study site affects chick performance other than during exceptional conditions rarely experienced.

In summary, chicks from both types of habitat were growing similarly, they were being fed the same number of times and attended for the same time by adults. Food does not seem to be a constraint on breeding success in either habitat.

Figure 5.1 Consistency of feeding transects data

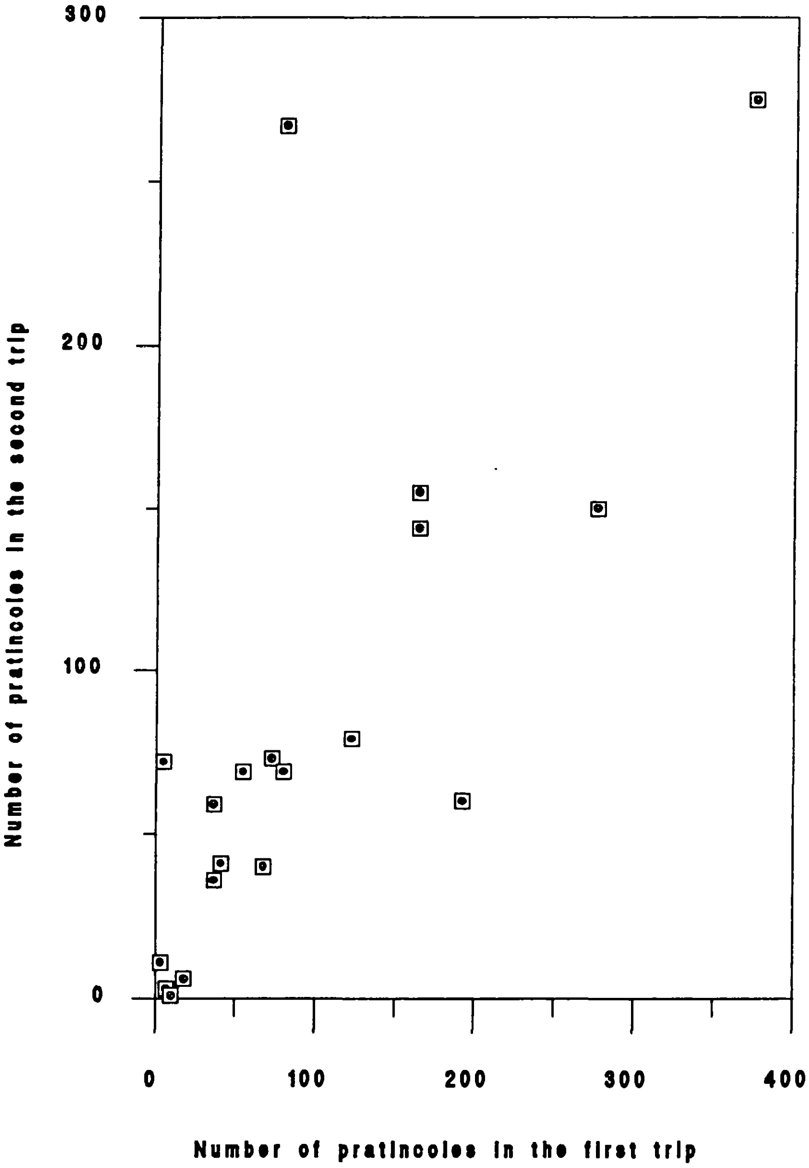


Figure 5.2 Percentage of days in which flocks were/were not formed

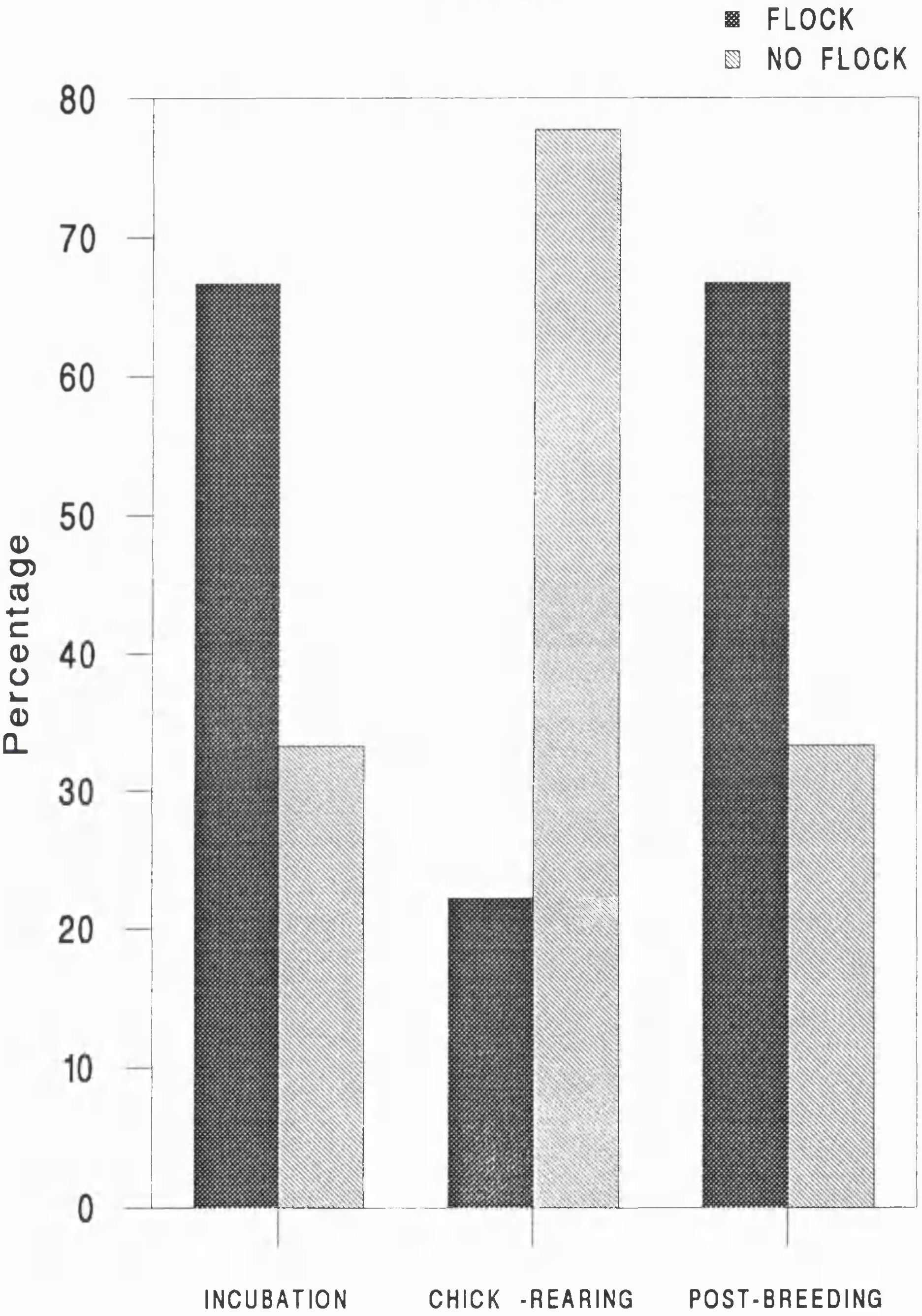


Figure 5.3 Pratincole feeding activity over an area of reeds and cereal crops through the day

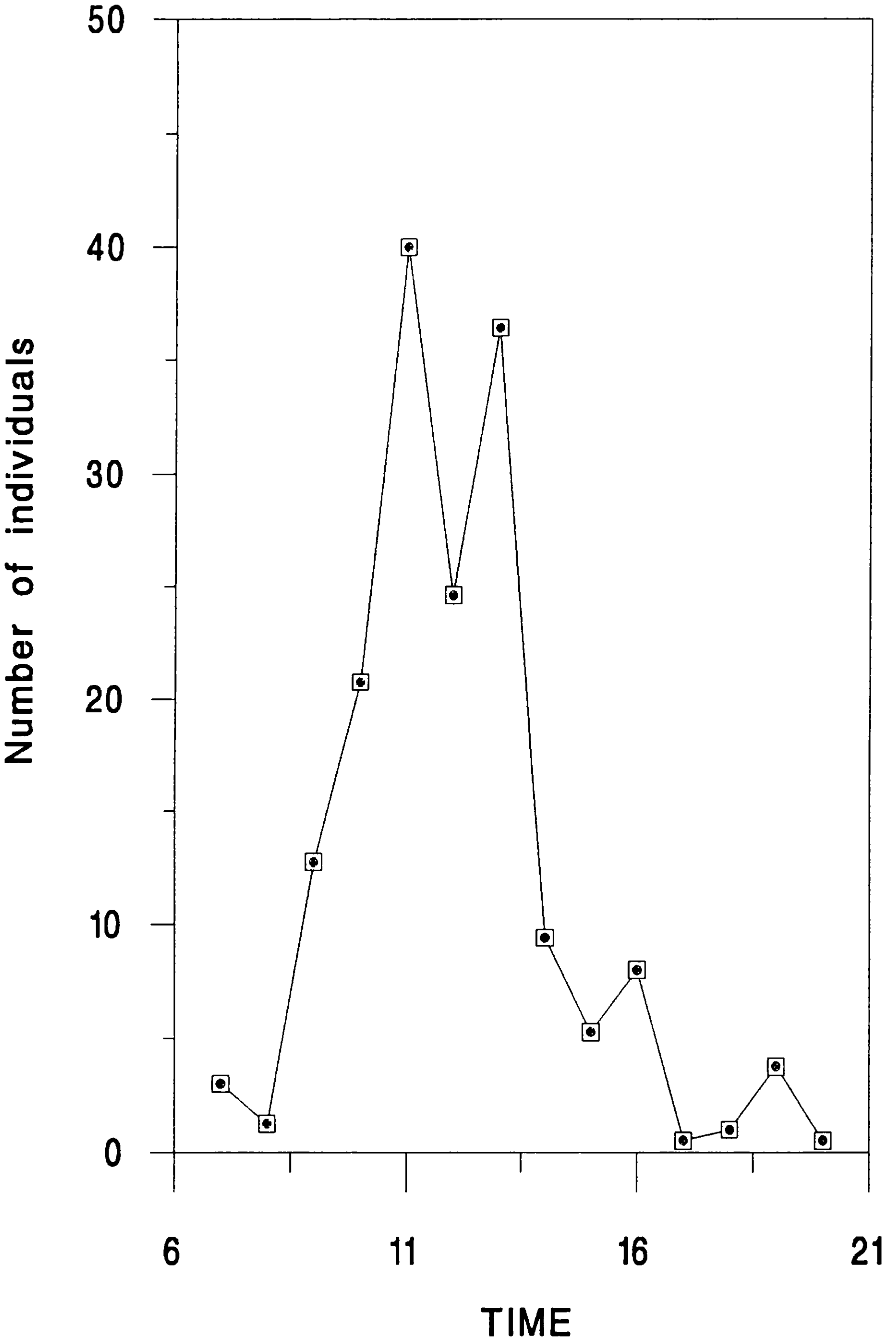


Figure 5.4 Number of taxa in faeces from marshland and farmland

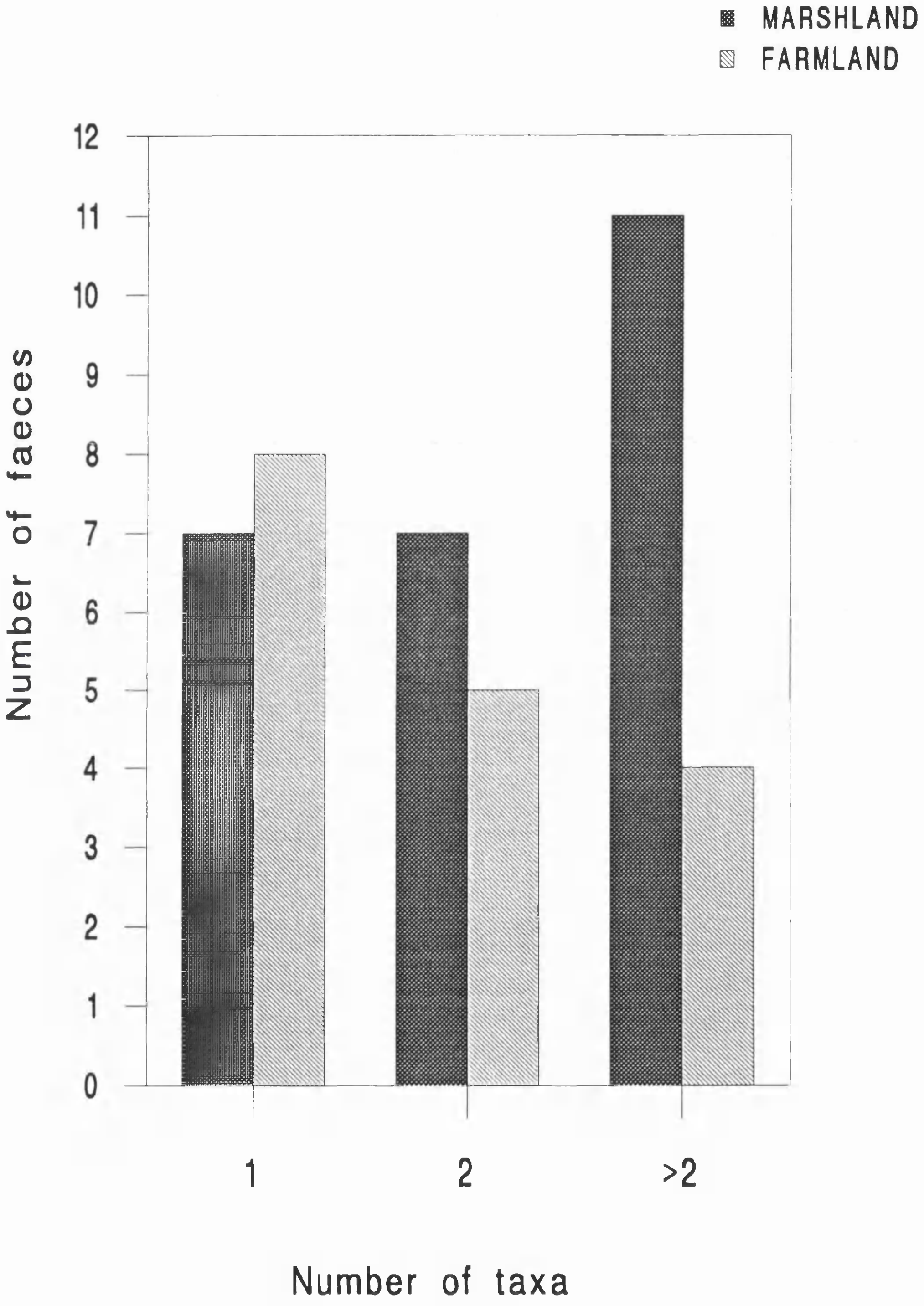
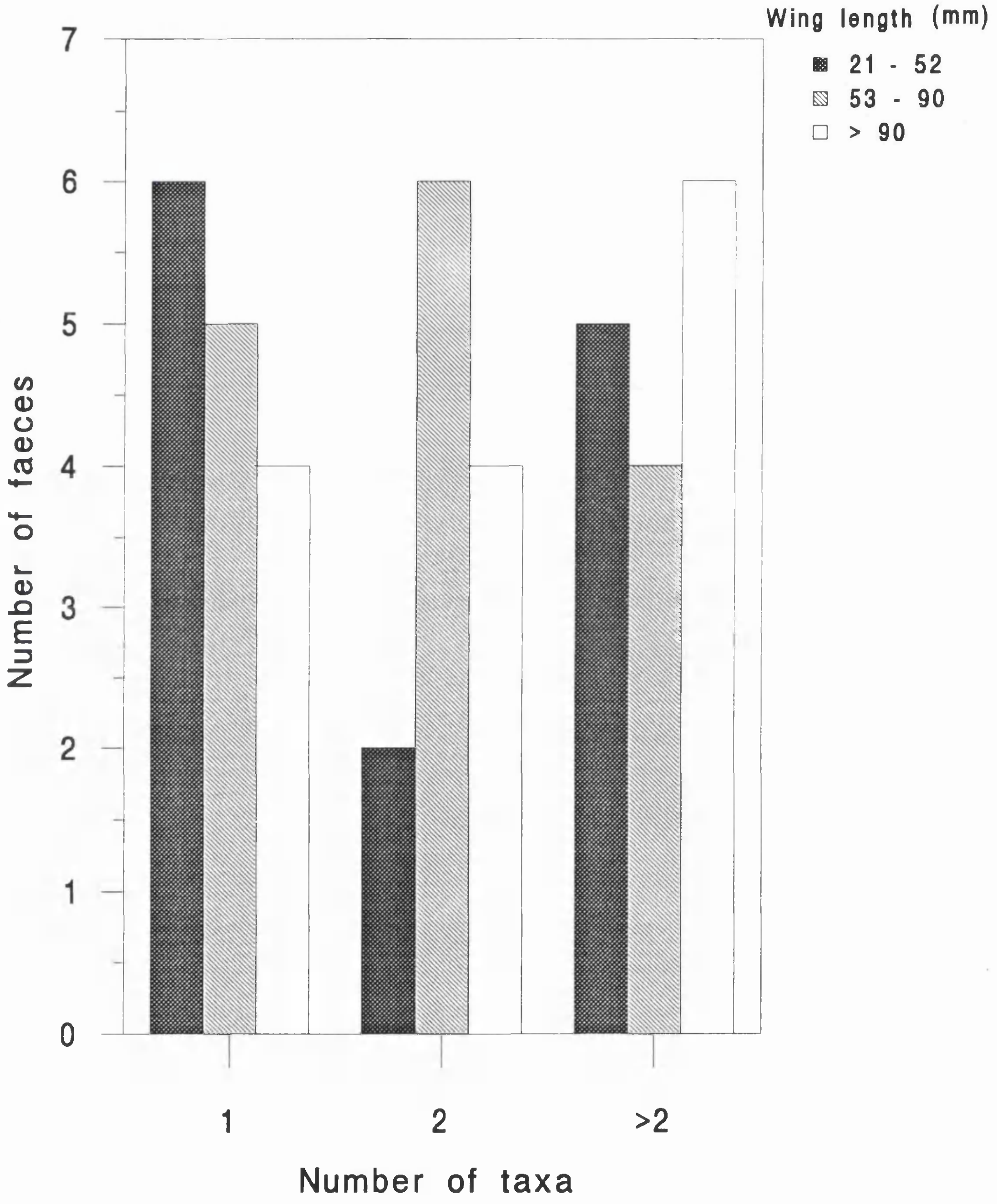


Figure 5.5 Number of taxa from faeces of chicks at different stages of development



CHAPTER 6

PRATINCOLE BREEDING SUCCESS

INTRODUCTION

Finding wader chicks to check survival is a rather difficult task as chicks are very cryptic. They can also move long distances from the nesting site. Indirect methods such as locating broods through marked adults have been used for waders and other cryptic species (Green 1984, Hill 1985, Gaines and Ryan 1988, Galbraith 1988a). Erwin & Custer (1982) suggested the use of enclosures around the nest for this kind of species. They discuss the problems that may arise using this method.

Many of the studies on wader breeding success are aimed at evaluating the impact of different habitats on breeding success (Skeel 1983, van Impe 1988). Wader nesting habitats have been widely transformed into agricultural areas and, at present, there are many species breeding on agricultural land (Chapter 1). Fledging success has been found to be lower in less natural habitats for curlew (Berg 1992) and lapwing (Galbraith 1988a, Baines 1990, Kooiker 1990), production not being enough to maintain the present numbers.

Collared pratincole populations are suffering declines in Europe (Chapter 1). Different reasons have been proposed for this such as loss of habitat, less food availability due to the use of chemical products on crops or reduction in the number of cattle (Sterbetz 1974, Uhlig 1989, Nadler 1990). It has already been shown (Chapter 4) how pratincoles have suffered an important loss of natural habitats in the study area. Yet, many birds keep on breeding in the transformed lands. To know the suitability of these for pratincoles to breed and the population trends, breeding performance in natural and transformed habitats was studied. There are intrinsic factors affecting individual productivity such as age or experience (Sydeman *et al.* 1991, Rockwell *et al.* 1993) which can only be investigated by long-term studies of marked populations. External factors such as food availability (Chapter 5), predation, human disturbance, land-use, or weather are considered here. Up to 1983 there were no data on collared pratincole breeding success (Cramp & Simmons 1983). Afterwards, very few studies have given information on this (Dolz *et al.* 1989, Pozhidaeva & Molodan

1992) and nothing has been done on their breeding success in the study area until the present work. In this chapter I compare nesting success in marshland and farmland and analyze the factors that influence it.

METHODS

1. Factors affecting breeding performance

Three types of factors were considered, those related with human activities, predators and weather. The first includes: direct disturbance (by people, vehicles, aeroplanes, helicopters, hunting) and agricultural activities (tractors, cattle, sheep, horses). The effect of agricultural activities was recorded in the study colonies (Chapter 3). This and predation were the only quantified disturbances as they were considered to be potentially the ones most to affect collared pratincole breeding performance. Discussion of possible effects will be given for all the factors above.

Four 13.5 hour watches were carried out during the incubation period and four during chick rearing in 1990 to observe the reaction of pratincoles to different disturbances. In 1992 observations were aimed at recording disturbance by avian predators. The number of hours of observation and the periods considered were the same as for 1990. Two marshland colonies and two farmland colonies were monitored in both years. Predator distribution in the area is not clearly associated with habitat distribution as marshes are patchily distributed within farmland. The chances of being disturbed by an avian predator are not related to the colony being on marshland or farmland, but to the presence or absence of those possible predators in a given area at a given time. For this reason, no comparison between habitat or years is made.

Watches started at sunrise and ended at sunset. The time and nature of all disturbances occurring in the colony and the general reaction to them were recorded. The response may vary from one individual to another, so the general reactions of all individuals under observation was used.

Bird response to disturbance was classified as follows:

1. No reaction.
2. Fly and move nearby, generally without alarm calls.
3. Flee.
4. Fly over the area, generally with alarm calls. No mobbing.
5. Fly over the area, some of them mobbing the intruder. (Different levels of intensity).
6. Distraction lure display (Injury feigning).

2. Reproductive success

2.1 Hatching success

Hatching success was recorded in the marshland and farmland colonies (Chapter 3). The method for nest location and marking has been described elsewhere (Chapter 2). The incubation period for a complete clutch was considered to be 18 days. The day that the first egg hatches was considered to be the end of this period. A nest was considered successful if at least one egg hatched. A clutch was considered to have been predated if obvious remains of predation were observed or, if not, 1. Hatched shell fragments, excrements or down were not found in the nest cup, 2. The whole clutch disappeared when it was known by its incubation stage that hatching had not been possible. Visits were close enough (every third day) to be able to rely on these criteria.

Different methods for calculating nesting success have been proposed (Mayfield 1961, 1975, Bart & Robson 1982, Klett *et al.* 1986). It has long been known that the traditional method of calculating the fraction of successful nests (or whichever unit is considered) may overestimate the success as nests that are lost before being found are not included in the calculations. The probability of detecting a successful nest is also higher as they are active for longer. All nests should be found when initiated which, in many cases, is nearly impossible.

Mayfield (1961,1975) proposed a method to overcome this problem. Nests found at any time during the incubation stage and those of unknown outcome can be used. The method has been widely used in the last decades and it has been described and evaluated by some authors (Johnson 1979, Hensler & Nichols 1981, Willis 1981, Erwin & Custer 1982, Hensler 1985, Klett *et al.* 1986, Johnson & Shaffer 1990, Beintema 1992). Mayfield bases his calculations on the time a nest is under observation (exposure), using nest-day as a unit. When there are significant losses of eggs (or chicks) without the loss of the entire nest it is advisable to use a smaller unit (egg-day) to calculate success (Mayfield 1975). The procedure is the same as explained above. This is not the case with collared pratincoles, so nest-day will be used as a unit for calculating hatching success.

Daily nest mortality (M) is calculated dividing the total number of losses (L) by the total number of nest-days (T): $M = L/T$ (I).

From (I) Mayfield calculated the daily survival rate (S), $S=1-M$, and considering the whole length of the period studied (n), the survival over that period SR is obtained, $SR = S^n$.

It is assumed that the mortality rate is constant and Klett & Johnson (1982) considered that if the variability is mild, the Mayfield estimator would be appropriate and not misleading. The mortality rate should be calculated for each period considered (e.g. laying, incubation, hatching, chicks) as survival is expected to be different (Erwin & Custer 1982). Klett *et al.* (1986) and Johnson & Sheaffer (1990) pointed out that in cases where a high number of nests is lost in a short period (e.g. due to weather, farming practices) the assumption of a constant mortality rate is obviously not fulfilled. Johnson & Sheaffer (1990) recommended the use of a different method in these situations. The loss of eggs in the study colonies located in farmland was not constant due to farming activities (Fig. 6.1). Estimation of hatching success was calculated by the apparent rate of nest success, as suggested by Johnson & Sheaffer (1990) for catastrophic egg losses and high synchrony. Because it was not possible to search the cotton field for replacement clutches this study includes only first clutches.

After Mayfield, nests that are lost between two visits are supposed to have been lost at the middle of the interval. Miller & Johnson (1978) suggested that the expected survival of a nest when visits are far apart is closer to 40% of the exposure period than to 50% as Mayfield proposed (also Johnson 1979). Collared pratincole nests were visited every third day, and I use 50% for these cases.

As two different methods were used to calculate hatching success in the marshland and farmland colonies, no statistical comparisons were made between them. The low number of unsuccessful nests in the marshland colony (4 out of 52) and the obvious reason for egg losses in the farmland colony, to be between plant rows, which masks the effect of other parameters, makes it useless to search for other factors affecting hatching failure in either colony. It is necessary to take into account that nearly all the nests were monitored.

2.2 Fledging success

Collared pratincole chicks are precocial and very cryptic which makes finding them rather difficult. They are able to leave the nest within the first few hours after hatching, but stay around the nest until the last egg has hatched. Adults and chicks can stay in the colony or move big distances from it, but even within an area they tend to move a lot. Erwin & Custer (1982) suggested the use of enclosures for this kind of species. This method was tried but the fence was not accepted by the adults. Also fences would restrict the high mobility of broods. Capturing adults and marking to follow broods was also tried, but no method worked (Chapter 2). For these reasons only hatching success could be assessed.

RESULTS

1. Reaction to disturbance

1.1 Human disturbance

People very seldom go into the colonies in marshland, except for snail collectors (from May to July) and farmers. Reaction to people inside colonies changes through the breeding season. At the beginning and at the end of the season pratincoles just fly and land a few metres away when disturbed. When they have nests they fly giving alarm calls and intensity increases when eggs hatch. It is in this period when they mainly show distraction-lure displays.

Most pratincole colonies in the study area are located in rather accessible places, as they breed mostly in agricultural land where there is an extensive net of non-asphalt roads. In general, they do not present any reaction to vehicles passing on roads nearby, although repair work on roads can deter them from nesting in the vicinity. Hardly any reaction was recorded towards trains, helicopters or aeroplanes. The last fly very frequently over the area as they are used to seed, reseed and spray rice fields from April to July.

Vehicles sometimes run over fledglings and adults. Both are fond of standing on roads, mainly at dusk. They react to oncoming vehicles by flying a few metres ahead, doing the same a few times until they finally fly back. They tend not to flush until the vehicle is very close. Hunting of collared pratincoles is forbidden by law (Ley 4/89 de 27 marzo de Conservación de los Espacios Naturales y de la Flora y de la Fauna Silvestre).

1.2 Farming activities

The effect of farming activities on breeding success of nesting birds will be considered later in this chapter. Their reaction to machinery working in the colony is in general flying and landing a few metres away or fleeing when approached. When incubating they present this same reaction but later on in the incubation period they stay on the nest until the tractor is very close, doing injury-feigning displays to it. Many farmers seeing this would spare the nest, although it is difficult to see the birds from the tractor and usually work on the field is carried out early in the breeding season when birds would fly away. In 1989 in the farmland colony the farmer saw 2 nests out of 49 when working on the land.

Most colonies in marshland have cattle at some point during the breeding season. Some colonies have sheep or horses (Table 6.1). They stay only temporarily as food is scarce by the end of May or beginning of June. They are present during the incubation period and past the hatching peak. In general, pratincoles do not react to the animals until they are very close, walking then a few metres away or flying nearby. This has been observed in birds both resting and incubating. A stronger reaction has also been observed with some birds flying around the animals with alarm calls, and others doing the distraction display.

Table 6.1 - Percentage of marshland colonies with cattle, horses or sheep present in 1990 and 1992.

	Cattle	Horses	Cattle + Horses	Sheep	None
1990 (n=28)	57.1	3.6	10.7	10.7	17.8
1992 (n=24)	41.6	8.3	4.2	12.5	33.3

1.3 Predators

Hardly any of the egg losses can be attributed to predators (Table 6.7). Kestrels (*Falco tinnunculus*), Montage's harriers (*Circus pygargus*), marsh harriers (*Circus aeruginosus*) and peregrine falcons (*Falco peregrinus*) have been seen preying on chicks. Potential predators in the area are listed in Table 6.2 (see page 99). The ones marked with anterisk are those which have actually been seen taking chicks. For the other species there are records in the literature for this area (mainly in the National Park of Doñana). There are no records of predation by rats (*Rattus* spp.) or reptiles although they are quite common here. Nearly all disturbances were caused by birds, mainly raptors. Pratincoles resumed the activity they had before the disturbance within 3 minutes of the potential predator leaving the colony.

The number of avian disturbances increases during the breeding season. This tendency was observed in both 1989 and 1992 (Table 6.3). Pratincole responses to raptors also increase through the breeding season (Table 6.4, $X^2=8.56$, df=2, n=185, $p<0.05$). The frequency of strong responses (score 5) increases when the eggs have hatched, from 31.6% of the total responses during incubation to 54.7% during the chick rearing period. The injury feigning response was never observed for avian disturbances.

Table 6.3 - Percentage of disturbances by raptors in pratincole colonies in 1990 and 1992 during the incubation and chick-rearing period. N=number of disturbances.

	Incubation	Chick-rearing	N
1990	42	58	90
1992	20	80	95

Kestrels and black kites (*Milvus migrans*) caused most of the disturbances in this area. They accounted for 91.8% in 1990 and 91.6% in 1992 of the total observed disturbances. When looking at the variation in response to these two species, pratincoles respond strongly to both, but especially to kestrels (Table 6.5). These are more difficult to deter from hovering over the colony whereas a softer reaction is enough to drive black kites out of the colony.

Table 6.2 - Potential pratincole predators in the study area. The ones marked with an asterisk are those which have actually been seen taking chicks.

	PREDATOR TYPES	
BIRDS	BLACK KITES	
	RED KITES	
	KESTRELS	*
	MARSH HARRIERS	*
	MONTAGUE'S HARRIERS	*
	PEREGRINE FALCONS	*
	BARN OWLS	
	RAVENS	
MAMMALS	DOGS	*
	WILD BOARS	
	FOXES	

Table 6.4 - Frequencies of pratincole response to disturbances by raptors (in a scale from 1 to 5, see methods) during the incubation and chick rearing periods in 1990 and 1992.

Reaction	Incubation (%)	Chick-rearing (%)
1	7	1.5
2	5.3	5.4
3	0	0
4	56.1	38.4
5	31.6	54.7
N	57	128

Table 6.5 - Number of disturbances caused by kestrels and black kites in pratincole colonies in 1990 and 1992 and pratincoles response on a scale from 1 to 5 (see methods). Total number of observations within each period=108.

	KESTREL		BLACK KITE	
Reaction	Incubation	Chick-rearing	Incubation	Chick-rearing
1	1	0	3	2
2	0	0	2	7
3	0	0	0	0
4	3	11	24	38
5	9	42	3	26

Other avian species (non-raptors) which have been chased out of colonies by pratincoles are gull-billed tern, cattle egret and little egret (*Egretta garceta*), the last two only recorded in 1992. All of them occurred during the chick-rearing period and the reaction was score 4 for cattle egret and 5 for gull-billed tern and little egret.

2. Hatching success

2.1 Collared pratincole hatching success

Hatching success for the marshland colonies was 91% and 73% whereas for the ones on cotton fields it was 35% and 12% (Table 6.6). Clutch losses in the marshland colony were due to predation and abandonment (Table 6.7, see page 102). Most deserted clutches had embryo development and were in the last days of incubation. The reason for these clutches being abandoned is not known. Of all eggs laid in the marshland colony, some 4%-7% were unfertilized eggs and some 3%-6% had dead embryos. One egg was squashed by cattle. Also four 1-2 day old chicks out of 120 were trampled (when still at the nest). Cattle density was 0.9 cows per hectare. The effect of trampling by horses will probably be small as they are usually at very low densities. It is likely to be different with sheep as they go through the colony in big compact groups.

Table 6.6 - Hatching success in the study colonies. Estimation of nests found represents the proportion of the total number of observed breeding pairs at a colony for which a nest was located.

	Hatching success	N	Method	Estimation of nests found
MARSHLAND 1	91%	47	MAYFIELD	90-95%
MARSHLAND 2	73%	9	MAYFIELD	90-95%
FARMLAND 1	35%	49	APPARENT	90-95%
FARMLAND 2	12%	16	APPARENT	30%

In the farmland colonies no predation on eggs was observed or inferred. Many of the clutches were destroyed by farming activities: all the nests laid between rows and some located on rows were buried. Others were abandoned during the days after disturbance (Fig. 6.2). There is a clear association between nest location and nest fate (Table 6.8, X^2=41.55, df=1, n=65, p<0.01). All nests between rows and 16 % (6 out of 37) of those on rows were destroyed by tractors. Of the remaining nests, 10 (32%) were somehow modified, generally by deforming the nest cup or partly burying the eggs. Six pairs rearranged the nest and went on incubating, but the other four abandoned their nests. Only 21 out of 65 nests (32%) were intact, but probably disturbance created by tractors and people working for two days in the field made eight of them abandon their nests.

Table 6.7 - N = Total number of clutches abandoned, destroyed and taken by predator in the study colonies.

	N	Abandoned	Taken by predator	Destroyed by agricultural activities	Squeezed	Others	Total losses
CLUTCH LOSSES							
MARSHLAND 1	52	2	2	0	0	0	4
MARSHLAND 2	12	3	1	0	0	0	4
FARMLAND 1	49	7	0	25	0	0	32
FARMLAND 2	16	5	0	9	0	0	14
EGG LOSSES							
MARSHLAND 1	141	14	5	0	1	1	21
MARSHLAND 2	27	7	2	0	0	0	11
FARMLAND 1	111	19	0	52	0	1	72
FARMLAND 2	40	13	0	23	0	0	36

Table 6.8- Pratincole nests destroyed and not destroyed related to their location (on plant rows or between them) in the farmland colonies. Yes = Nest abandoned/ No=Nest not abandoned. All nests not located on rows were destroyed.

	DESTROYED		NON DESTROYED (ON ROW)			
			Nest complete		Nest modified	
	On row	Not on row	Yes	No	Yes	No
FARMLAND 1	6	19	4	11	3	6
FARMLAND 2	0	9	4	2	1	0
TOTAL	6	28	8	13	4	6

Survival of nests on rows depends on the ability of the person driving the tractor to keep a straight line. It also depends on when they start to work on the fields. Figure 6.3 shows the different activities carried out in one of the colonies and the breeding phenology of pratincoles. The peak of laying was within the first ten days of May. Shortly after this, agricultural activity in the field was intense and egg losses were very high (Fig. 6.2 and 6.3). This pattern of agricultural activities is roughly the same for all cotton fields although the number of times they rake between rows, number of irrigations and chemical treatments and dates of activity may vary slightly between fields. In dry years, passes with a special implement which turns over the earth between plant rows (without leaving unturned bands at both sides of the plants) and normal passes turning over the earth (leaving some 10 cm at both sides of the plants), are frequent as the earth dries out very quickly. These passes allow the earth to absorb the maximum amount of water from the air.

Birds in the study area have been monitored for five years. Breeding performance in marshland and farmland was consistent between years within the same habitat except in farmland in 1993 when, because of an exceptional lack of water much of the farmland was not cultivated or crops were abandoned. This allowed pratincoles to achieve a higher hatching success than in normal years in this habitat.

2.2 Stilt and stone curlew hatching success

In the main study colony in marshland 21 nests of stilts and 3 nests of stone curlew were initiated at different times. Hatching success of both species was very high: 100% for stone curlews and 92% for stilts (Mayfield's method). Only one stilt clutch was lost. Nine out of the 10 eggs lost were abandoned and the other trampled by cattle. There was no predation on stilt or stone curlew nests. In the smaller marshland colony there were four stilt nests which hatched successfully. In the farmland colony all stilt nests (4) were destroyed by tractors on the first day of work on the field. They did not attempted to nest there again.

DISCUSSION

Cattle are a potential problem for pratincoles when trampling on nests or chicks as reported by Dolz *et al.* (1989) and Tomkovich (1992). This was not the case in the marshland colony, although cattle density was very high (0.9/ha). Beintema & Munskens (1987) found that with one cow per hectare nest destruction due to trampling was high for lapwing, redshank, black-tailed godwit and ruff *Philomachus pugnax.* Jensen *et al.* (1990) in an experimental study on cattle trampling on simulated ground nests found that the percentage of trampled nests increased with stock density. Also Brandsma (1991) and Stock *et al.* (1992) showed that higher numbers of different species were found in plots with less cattle pressure. In this study it may have been low because cows spent longer at one side of the field (away from the pratincole colony) where it was more humid and grazing conditions were better. This was also where the farmer would come to milk them. Cows were present all during the incubation period and past the hatching peak. The impact of cattle on chick survival is not known although pratincole chicks' habit of crouching in crevices in the ground or under the nearest tussock when disturbed may reduce their mortality by cattle trampling. But cattle also have positive effects, such as keeping vegetation short or encouraging dung-associated invertebrates (Chapter 4).

When the marshes were reclaimed for agriculture many of the mammal predators of pratincoles disappeared from the area, but the number of rats has probably increased. They are frequent in the area but the incidence of predation by them in the study colonies was practically nil. Predation on clutches was not recorded in the crop but predation on chicks was observed in both habitats. The main predators were kestrels, Montagu's harriers and marsh harriers. Peregrine falcons have also been seen taking them. Egrets were only seen harassing pratincole colonies in 1992. This could have been due to a lack of food for them as 1992 was a relatively dry year. Sporadically chicks are killed by dogs. Other sources of disturbance in this area are traffic, farmers and snail collectors. Pratincoles seem to adapt well to this sort of disturbance.

Weather during the breeding season can have an effect at different stages of the breeding cycle: settlement, nesting and chick rearing. It has already been shown how weather and the level of the water table can affect settlement in colonies (Chapters 3 and 4). Once the eggs have been laid, heavy rainfall can destroy nests and kill chicks (Csaba 1979, Dolz *et al.* 1989). The effect of weather on food availability and chick performance has been discussed in Chapter 5. Lack of food in very dry situations would be possible mainly in the more natural areas were no water is kept artificially. In such situations pratincoles might not even attempt to breed as happened in some colonies in the National Park of Doñana in 1992 and, to a bigger extent, in 1993 when hardly any pratincoles bred there. Both heavy rainfall and lack of water may have a stronger effect in marshland than in farmland where water level is controlled and there is water supply all during the breeding season. Nevertheless, there are some indirect effects on farmland as land use depends on weather and water availability (Chapter 4).

Hatching success in the marshland colonies was high. The smaller colony was frequently disturbed by people during that season and this could be the cause of nest abandonment. Similarly high hatching success was found by Dolz *et al.* (1989) and Pozhidaeva & Molodan (1992) in pratincole colonies in marsh habitats elsewhere. Percentages of unfertilized eggs and eggs with dead embryos were similar to those obtained by Pozhidaeva & Molodan (1992).

Hatching success in the farmland colony was very low as most of the nests were destroyed or abandoned due to agricultural activity. Agricultural work is the cause for clutch losses in several other wader species (Baines 1990, Berg 1992, Shrubb 1990), as traditional wader breeding areas have been reclaimed. Shrubb (1990) remarks how replacement after loss of first clutches due to agricultural activities is crucial to lapwing nesting performance. It is not known to what extent replacement clutches make up for the loss of pratincoles' first clutches. Some of the pairs stay in the colonies after losing their nests but others leave, possibly to breed elsewhere. Most of the nests are lost within the first 10 days of incubation. Sterbetz (1974) affirms that second clutches are laid in these cases, but pairs then choose a different place to breed. However, it is unlikely that hatching success in replacement clutches will be any higher than for the first clutches since agricultural activity tends to increase rather than decrease as the season progresses. Furthermore, many crop fields will become unsuitable for pratincoles to nest in as the height of crops increases.

A situation like the one in 1993 when farmland (mainly sunflower fields) was more used than marshland, and when hatching success was probably high in farmland, is exceptional. In normal years pratincoles do not settle much in sunflower fields as when plants grow vegetation cover is too dense (Chapter 4). Hatching success would not be high as some farming works are carried out on the crops. Instead, pratincoles settle mainly in cotton fields where hatching success is rather poor.

Figure 6.1 Clutch losses due to agricultural activity

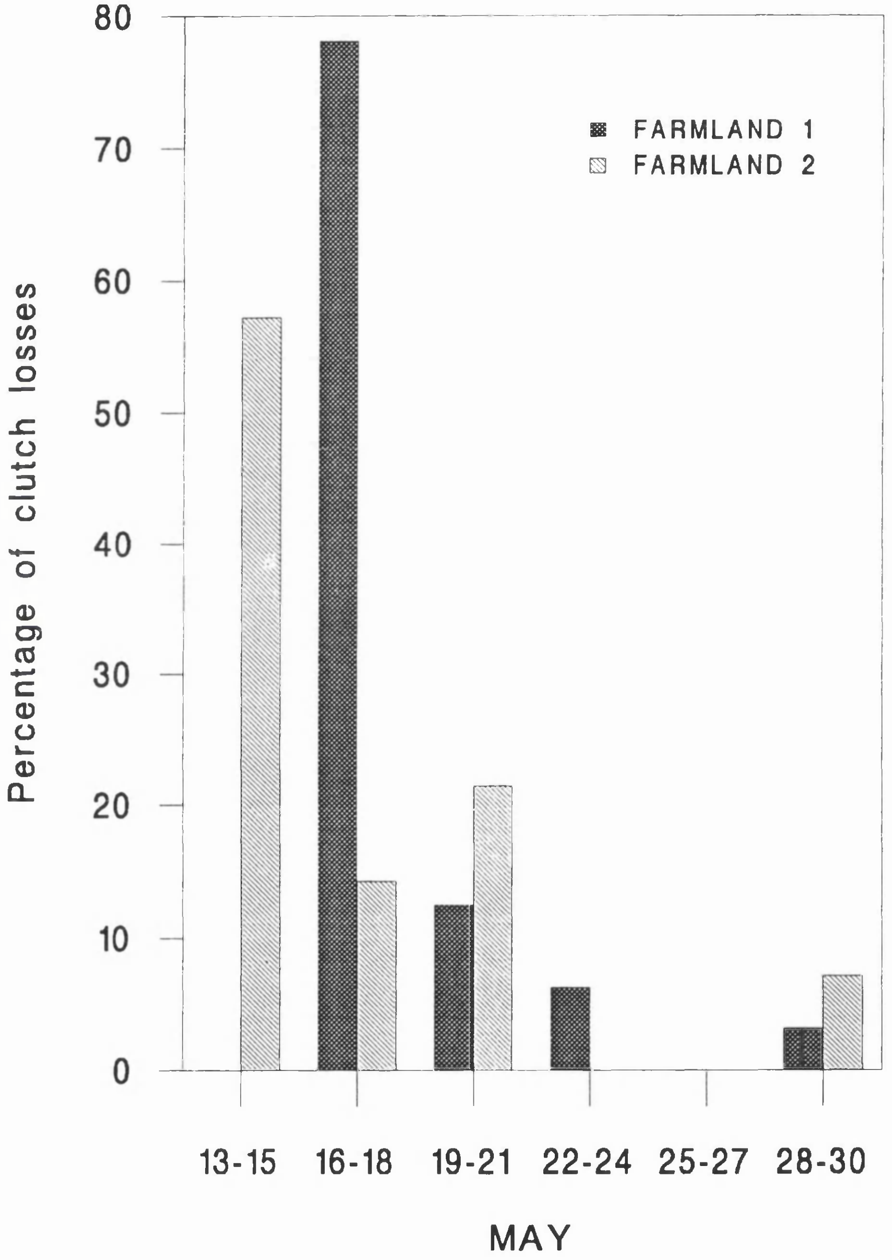


Figure 6.2 Number of Collared pratincole clutches destroyed and abandoned as a result of agricultural activities in the farmland colony

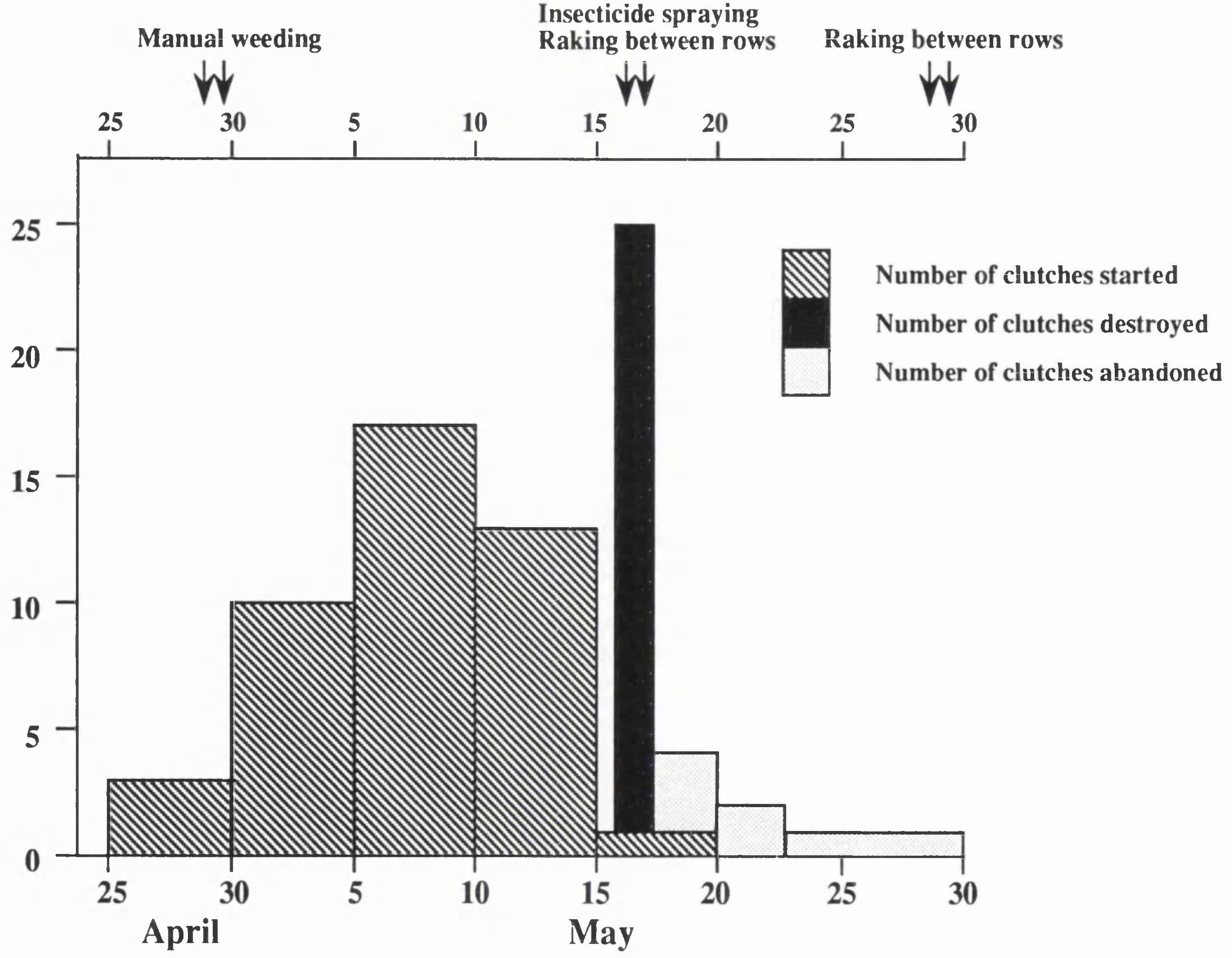
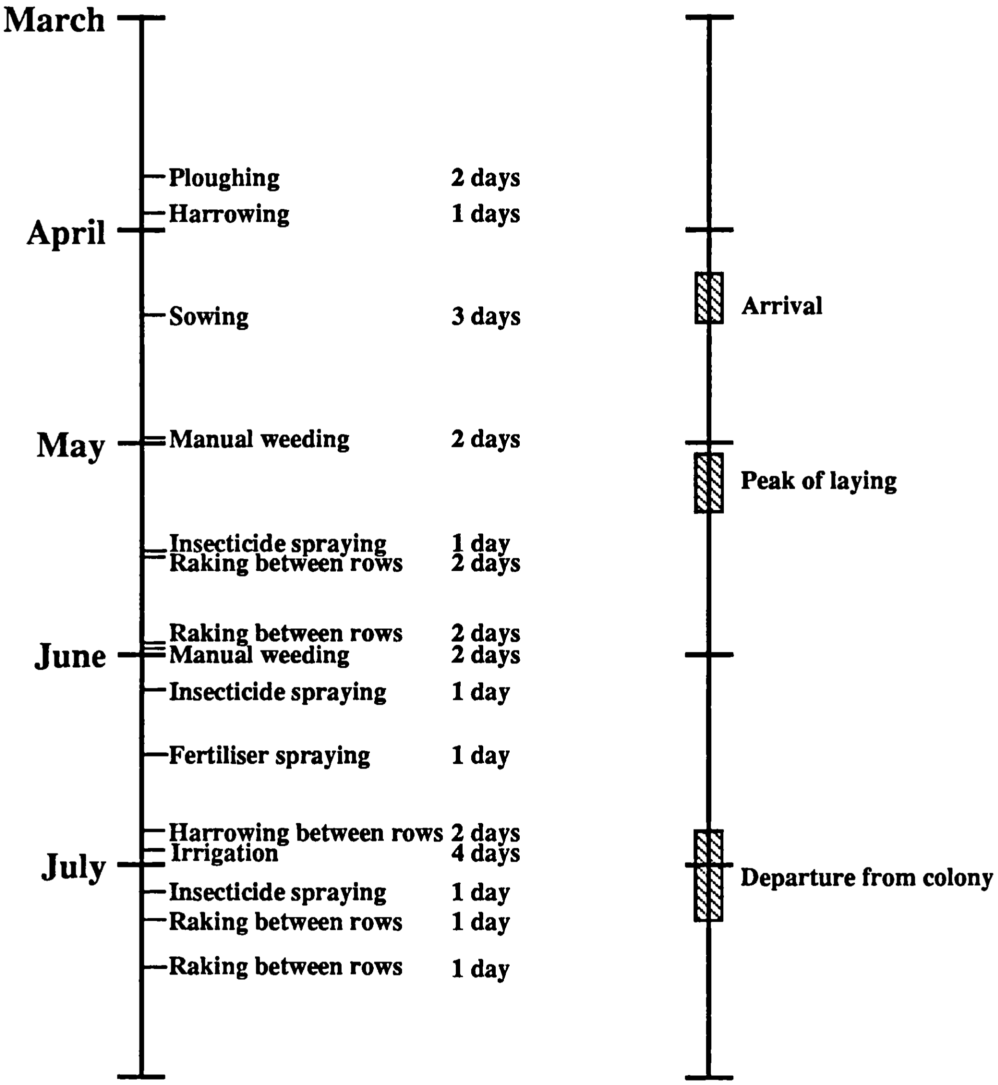


Figure 6.3 Agricultural activities and Collared pratincole phenology in the farmland colony



CHAPTER 7

PRATINCOLE ECOLOGY AND IMPLICATIONS FOR CONSERVATION

1. GENERAL CONSIDERATIONS

Collared pratincoles nest by preference in marshland rather than in farmland in the study area, although an important part (about half) of the population settles in farmland. When comparing food availability in colonies in marshland and farmland in the area of the marshes of the Guadalquivir river, the former had slightly more food available than the latter. But due to the patchily distribution of the marsh and reed fragments in the area (preferred feeding places and where food is more abundant), food is probably not a constraint in either habitat. Chicks from marshland and farmland grew similarly, were fed the same number of times and were attended for the same time by adults. In the colonies further inland, wetlands are much more scarce and food availability could be less than in the Guadalquivir marshes region. A small amount of data from inland sites showed that chicks there were growing less well (Chapter 3). Unfortunately there are data from only one colony in one year and there is no information on food availability, number of feeds and adult attendance in this area.

The only pronounced difference found between pratincoles in a natural marshland colony and pratincoles in farmland colonies is their hatching success, being much higher in the former. In farmland most nests are destroyed due to farming activities. Since a high proportion of the population now nests in the "improved" agricultural habitat, these differences have profound implications for the population. In farmland a reduction of numbers would be expected due to some adults not going back (due to bad breeding performance) and/or to a lower production of chicks. In the study sites numbers have not decreased drastically from 1989 to 1993 but it is known that there has been a long-term decline of the whole breeding population in the area and that pratincoles no longer breed in some traditional breeding places which were transformed into farmland.

The nature of adults breeding in each habitat is unknown as I was not able to mark them. A higher proportion of big clutch sizes and bigger eggs being laid in the colony in marshland than in the colony in farmland, may indicate a better quality of birds (more experienced individuals) or better food availability in the former. This last point is probably not the case as explained above. At this stage there is no information to accept or refute any hypothesis regarding adult quality in either habitat.

If losses during the incubation period are high in the farmland colony, why do they keep on breeding in crops? Székely (1990) suggested that a lack of more natural habitats and a rich food availability in man-made habitats (lower breeding success) made kentish plover breed in them. In this study, food availability was not higher in the man-made habitat. It could also be argued that there is not enough marshland for them and they use farmland instead. This is the case when most of the marshland surface is not dry enough at the time of settlement (Chapter 4). But in normal years, not all the apparently adequate marsh fragments are used as colonies. Nevertheless, the area of marshland is very much reduced and may not be enough to support the pratincole population in the study area. It may also be that pratincoles show strong colony-site fidelity and tend to go back to the same colonies to breed. Certainly, colonies are formed in the same areas year after year. In fact, most of the colonies at present located in farmland, were previously marshland. Also the timing of colony formation in both habitats is very similar: pratincoles do not fill all marshland fragments before farmland ones. A long-term study of fledging success and population recruitment and movement between colonies would help to elucidate this. Galbraith (1988a) suggested that lapwings kept breeding in arable farm (lower breeding success) because changes in land-use were too recent and the habitat had become less suitable for breeding only relatively recently. Thompson & Coulson (1992) found this species is highly philopatric and shows a high degree of breeding site-fidelity. The fact that marshes may be a poor breeding habitat in certain years due to unusual weather, and that high hatching success can be achieved in exceptional years (e.g. 1993) in agricultural areas (when fields are abandoned by farmers), may partly counterbalance the normal superiority of marshland as a breeding habitat.

2. MANAGEMENT

The most serious hazard that collared pratincoles face in the study area is the loss of habitat. The pratincole population outside the National Park of Doñana is at least three times that inside the park. Altogether pratincoles in this area (more than 3000 pairs) represent 80-85% of the Spanish population (Calvo *et al.* 1993). Considering that most of the pairs nest in reclaimed land (either in crops or in marsh fragments) measures to keep them in good condition as well as any sort of management for farmland would be desirable. Otherwise a further decrease of the breeding population can be expected.

An effort should be made to preserve pratincoles' natural breeding habitats left in the area. Most of the colonies in the study area are not included in any protected zone. Some marsh fragments are still being destroyed and some others are used as dumps for rubbish and plastic used in surrounding farmland. Many of these could be recovered to marshland. Although predation by rats was not an important factor in the study colonies, rats are abundant and could present a hazard requiring control. These protection measures would not only benefit pratincoles, but also stilts, kentish plovers, stone curlews and some lark species *Alaudidae*, which also nest in marshland.

Some management measures are specific to colonies in marshland or in farmland. The effectiveness of these suggestions has yet to be determined.

2.1 Colonies in marshland

a Grazing - Even if the effect of cattle in this study was negligible, this may not always be the case in pratincole colonies. It should be advisable to keep cattle in low densities or out of the colonies during pratincoles' breeding period but to encourage grazing outside this period.

b Vegetation cover - Where vegetation cover and height cannot be kept at a low level through grazing, artificial control of vegetation would be desirable.

c Water level - In special circumstances, when soil humidity would deter settlement in a high number of marshland colonies, artificial drainage of water would avoid most of the population breeding in agricultural land. Marshland should otherwise be left to refill and dry up following the natural cycle. This measure should only be carried out in marsh fragments known to be used by pratincoles and in which other species would not be affected.

2.2 Colonies in farmland

This study has identified the loss of eggs from nests in farmland as a result of agricultural activities as the overwhelming determinant of breeding success and as a possible cause of declining pratincole numbers. Pratincole colonies in farmland are formed year after year in the same fields. Now that the location of most of the colonies in the area is known management in them could be carried out.

Depending on the crop different points have to be taken into account. I will consider the three main crops in the study area: rice, sunflower and cotton. All colonies in rice fields are destroyed when planting starts. This usually occurs at very early stages of pratincole settlement. In very dry years (as 1993) fallow lands - including rice fields which are not seeded - and sunflower fields offer an alternative to pratincoles. If left undisturbed until chicks have fledged, success will probably be high. The same would be desirable for any fallow land with pratincoles breeding on it in any given year. In years when water is available for irrigation, most of the colonies are located in cotton fields where egg losses are high due to agricultural activities. Here, a delay of two weeks in the start of works with machinery (raking and insecticide spraying in May) would probably be enough to allow most of the clutches to hatch. Chicks in crops tend to move away from the point of disturbance, being, in theory, possible to drive to the sides of the field where they would be safe while work is being carried out within the crop. However, the actual effect of machinery on chick survival is not known yet. This single simple measure could increase hatching success in this habitat.

This presents some difficulties, such as the requirement for a person to determine the exact location of colonies and their stage of incubation and driving chicks away from tractors. It would require some economical compensation to the farmers as well. This measure would be difficult to undertake as, as said above, most of the colonies are not included in protected areas and because it would require collaboration between the government and farmers as in other management programs (Schuefler & Stiefel 1987, Brandsma 1991). Management strategies concerned with the problems of birds (including waders) breeding in British farmland habitats are found in Lack (1992). Although at present there is no management plan for pratincoles or any other bird species breeding in farmland in the study area, a growing interest in conservation matters will hopefully change the present situation.

There is no information on the effects that pesticides or fertilizers have on pratincoles when spread on eggs, diluted in the water in irrigation ditches where birds drink or in the insects they eat. Analyses of pollutant contents in pratincole eggs from the National Park of Doñana are found in Hernández & Baluja (1976). The use of pesticides and herbicides are considered as one of the threats for pratincoles in the Red Data Book of Spanish Vertebrates (Blanco & González 1992).

2.3 Feeding habitats

Although food does not seem to be a constraint it is more abundant in marshland. Pratincoles use significantly more areas with reeds and shallow waters and fragments of marsh vegetation for foraging than they use crops, except cereals (Chapter 5). It is important for pratincoles that the few wetlands left in the study area are kept in good condition. This could be of great importance for the survival of the colonies located inland where there are hardly any wetlands left.

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APPENDIX 1

Ringing & Migration (1992) 13, 129–151

A review of the use and the effects of marks and devices on birds

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This paper reviews the use and the effects of marks and devices on birds. Although most papers reporting research on birds make use of marks or devices, very few studies test for harmful effects or data biases caused by these. Many research projects have used marks and devices without encountering any harmful effects of these on the birds being studied. However, where assessments have been made it is clear that all of the methods of marking can have adverse effects, while most devices attached to birds do alter their behaviour to some extent. We conclude that more attention should be given to these effects before the normal assumption of no influence on the biological parameters being studied can be made with confidence. There is a need for careful tests of the effects of marking methods to be undertaken. We hope that this review will assist people studying birds to plan their use of marks and devices in such a way as to minimize problems caused by these research tools.

Ringing and dye marking of birds to assist in studies of survival, migrations and aspects of ecology are well-known and important techniques which have been used for many decades. In the vast majority of publications using these techniques there seem to be no adverse effects of marking on the birds. In more recent years, there has been an increasing development of much more sophisticated means of marking (leg flags, wing tags, back tags, neck marks, nasal marks and others) and also the construction of miniature data logging devices (altimeters, depth gauges, speedometers, activity recorders) and radio transmitter packages. It is immediately evident from the literature that many authors report research using these marks or devices without any consideration of the effects these may have on the birds. One reason for authors to omit reference to biases caused by marking may be the desire of editors to remove all unnecessary material from papers to save space in journals. Such a practice would seem sensible providing the technique used has been well established as not altering the aspects of bird biology being studied. It was because we felt that this may not always be the case that we undertook this review.

Gavin (1989), in a review of marking procedures and their use on different animals, says that publications on birds less commonly use marking than studies of reptiles or mammals. He attributes this to the fact that birds are more conspicuous, and so marking is not necessary for certain kinds of study. Nevertheless, up to 51% of the papers he reviewed used some marking method. Marking techniques for birds have been reviewed by Marion & Shamis (1977), Patterson (1978), Spencer (1978), Day *et al.* (1980), and MacClure (1984), but these reviews give little information on adverse effects of marking. Kenward (1987) recently reviewed the use of radio transmitters on birds and considered in some detail the effects of different tag attachment methods.

In many countries the licensing of individuals to use rings and particularly to use more complex marks and devices is strictly controlled by a national authority and all planned uses of marks and devices are screened to ensure that hazards to birds are minimized. The British Trust for Ornithology (BTO) has already adopted this review to assist them in assessing proposed studies. Such quality control procedures and the high standards of ringing training result in few studies in Britain producing marking-induced effects on birds; most of those reported here are from work carried out overseas, and many of the methods that caused problems with particular species in the past are no longer used for those species. Nevertheless, marking methods that can influence survival and behaviour are still used and deserve attention so that any hazards to birds can be minimized.

This review is in two parts. Firstly we briefly present a quantitative review of the marking methods and devices used in studies published in several selected leading bird journals in recent years, in relation to the authors' consideration of bias that marks and devices may induce. Then we consider the extent to which the methods have been demonstrated to provide unbiased results, by reviewing research published throughout the scientific literature.

Human presence can alter bird behaviour even when this is not immediately evident (Wilson *et al.* 1991). There have been several studies on effects of trapping and handling (Leberman & Stern 1977, Busch *et al.* 1978, Blokpoel 1981, Brubeck *et al.* 1981, Nisbett 1981, Ueda 1984), and this process can be disturbing, leading to nest desertion or changes in behaviour. Influences of disturbance, trapping and handling on subsequent behaviour are outside the scope of this paper, but it should be borne in mind that changes in behaviour of birds could be caused by human disturbance, by trapping and handling, by marks or devices attached, or by combinations of these.

METHODS

We reviewed 786 papers on birds in Auk 1979–1989, Ibis 1975-1990, Journal of Applied Ecology 1975–1989, Journal of Wildlife Management 1975–1989 and Ornis Scandinavica 1977–1989. From each paper we recorded the technique(s) used, the subject of study and any comments on effects. The subjects of the papers were classified into very broad groups: 1 Moult, age, body condition, growth patterns, morphology; 2 Movements and survival; 3 Ecological studies; 4 Papers on the development of techniques.

Papers were classified according to the consideration given by the author to effects of the mark or device on the birds as:NC – No comment, C – Comment on effects but without expressly testing ("...the birds seemed unaffected...", "...behaved normally after the..."), T – Tested in relation to any parameter(s) (predation, reproductive success, return rate, behaviour, etc.). In addition, we reviewed papers throughout the scientific literature, dealing directly with effects of marking techniques, papers using them for another purpose and finding effects on the birds, and papers describing techniques. We did not consider papers based on individuals kept in captivity, unless the results were relevant for the aim of this review. Neither do we consider those in which the mark was internal (e.g.implanted radio–transmitters) or involved clipping or removing of feathers or nails, although such techniques undoubtedly can have effects on bird behaviour and survival.

We grouped the techniques as follows: 1 METAL RINGS, 2 COLOUR RINGS, 3 MARKS ATTACHED TO THE LEGS (Tape, leg streamers, leg strips, leg flags, flipper bands, thread around the leg, web tags, toe banding), 4 WING TAGS, 5 BACK TAGS, 6 NECK TAGS, 7 NECK COLLARS (Including laces and bands), 8 NASAL MARKS (Saddles, discs) 9 DYES, 10 OTHER MARKS, 11 DATA LOGGERS (Digital watches, altimeters, depth gauges, speedometers), 12 RADIO–TRANSMITTERS.

RESULTS

Frequency of use of marks and devices

Of the 786 papers reviewed, 39.6% used colour rings, and 38.3% used metal rings. 98% of the studies in which rings were used did not mention possible effects of the rings, 1.3% made a brief comment, and only 0.7% tested for any bias caused by rings (Table 1). Similar patterns were found for most of the other marks, although slightly more authors considered problems caused by wing tags and neck collars. Transmitters have been used for many years and some side effects have been found on birds wearing them (see below). Data loggers have started to be used more recently. This group has the highest percentage of studies in which effects have been checked or commented on (75%).

The consideration given by authors to biases caused by marks or devices shows a historical trend in two cases: neck marks and radio transmitters. The former were tested in many papers in the 1970s (67%) and rarely subsequently. The latter has a high percentage of papers in which the method is either tested or with comments about effects, although there seems to be a slight tendency for those without any comment to have increased in recent years.

Metal rings

Rings are by far the most common means of marking birds, but are often combined with other marks. Most of the authors assume that rings have no effect on the birds, and make no comment at all about this (98%). Even when they have been used in works considering the

Table 1. Frequency of use of different marking techniques and employment of devices on birds in 786 papers published in Auk 1979–89, Ibis 1975–90, J. appl. Ecol. 1975–89, J. Wildl. Manage. 1975–89 and Ornis Scand. 1977–89.

Mark	*Number of papers in which technique was used*	*No Comment*	*Comment*	*Harmful effect reported/ tested*	*Breeding or feeding ecology*	*Movements or survival*	*Morphology moult, growth age or body condition*	*Technique develop- ment*	*Percentage papers with references*		
									<1980	*1980- 1984*	*>1984*
Metal ring	301	98.0	1.6	0.3	67.1	21.9	10.2	0.6	3.5	0.0	2.7
Colour ring	311	98.0	0.9	0.9	81.6	11.5	4.5	2.2	0.0	0.0	3.5
Leg flag	32	96.8	0.0	3.1	75.0	12.5	3.1	6.2	20.0	0.0	0.0
Wing tag	65	87.6	3.0	9.2	72.3	15.3	3.1	9.2	0.0	26.6	3.1
Back tag	8	75.0	12.5	12.5	62.5	25.0	0.0	12.5			
Neck collar	33	78.7	3.0	18.1	39.3	33.3	9.1	18.1	66.6	13.3	9.1
Nasal mark	20	90.0	5.0	5.0	85.0	5.0	0.0	10.0	0.0	10.0	14.3
Dyes	64	90.6	9.3	0.0	85.9	7.8	4.7	1.5	0.0	13.0	10.0
Other marks	40	97.5	2.5	0.0	85.0	7.5	7.5	0.0			
Data logger	8	25.0	12.5	62.5	50.0	12.5	0.0	37.5			
Radio transmitter	187	66.3	15.5	18.1	40.6	43.8	1.1	14.4	42.4	33.9	30.6

effects of certain types of marks on birds, the effects of the rings have almost always been ignored, and the ringed birds have generally been used as controls against which to compare the effects of more substantial marks or devices. Although the vast majority of studies using rings give no reason to suspect that any adverse effects are caused, some problems with a few species wearing rings have been reported. The use of metal ring can cause leg irritation as reported by Law (1929) in Rufous-sided Towhees *Pipilo erythrophthalmus.* Reed (1953) and Elder (1984), reported some cases of leg mutilation when using two rings, one above the other on the same leg. The rings deformed producing sharp edges that caused injuries to the leg. Metal rings used singly also wear as a result of abrasion against the leg, and the rate of wear varies among species (Harris 1980). Worn rings become sharp and will eventually open and slide off the leg. Perdeck & Wassenaar (1981) showed that ring wear is less on the tibia than on the tarsus, but no mention was made of any effects of this on the birds, though rings which wear less quickly are likely to be less hazardous to birds. Incorrect adjustment of the ring can cause injuries to the bird's leg. Herholdt (1987) found a dead White Stork *Ciconia ciconia* whose ring had not been closed properly and it had slipped over the tibial joint, damaging the leg tissue.

Rothstein (1979) noted that White-crowned Sparrows *Zonotrichia leucophrys* with metal rings developed a grey cast on the tarsus, presumed to be due to an oxide produced from the ring. He also detected that the tarsus with the ring increased in diameter, although no deleterious effect was observed. Swelling of the leg has also been found with Red-winged Blackbirds *Agelaius phoeniceus* (Cummings 1987) and Spruce Grouse *Dendragapus canadensis* (Robinson 1980), in both cases due to the ring being too tight.

In species which "defecate on the legs" such as Turkey Vultures *Cathartes aura,* the excrement can accumulate between the leg and the ring (Stewart 1985). Schulz (1986), studying White Storks, observed that 50% of all the birds carrying a ring had injuries caused by the accumulation of excrement in the ring, and he estimated that this increased the annual mortality rate by at least 5%. In vultures the accumulation can cause the foot to swell (Sweeny *et al.* 1985) and eventually the use of the leg or foot is lost (Henckle 1976).

Accumulation of ice in the ring and subsequent leg injuries and even leg loss, has been reported in tits *Parus spp.* by Dunbar (1959) and in American Goldfinches *Carduelis tristis* by MacDonald (1961).

No effect of metal rings on behaviour was noted by Robinson (1980) in a study of Spruce Grouse, or by Prendergast (1975) who reports how Chiffchaffs *Phylloscopus collybita* and Kestrels *Falco tinnunculus* resumed their feeding activities immediately after having been caught and ringed, showing no interest at all in their rings. Dhindsa & Boag (1989), in an experiment with Magpies *Pica pica,* found that ringed and unringed individuals showed no differential sensitivity to observer approach.

Dickson *et al.* (1982), in an evaluation of marks for Cardinals *Cardinalis cardinalis,* did not comment on any effect of metal and colour rings on the birds. By contrast, a very strong reaction to metal rings has been described several times for this species (Young 1941, Laskey 1944, Lovell 1948). Wiseman (1977) attributes the problem of band removal by Cardinals to "individual temperament", as only some birds would not accept the rings (he considers colour rings as well). Another species which has shown a strong reaction to the ring is the Black-capped Chickadee *Parus atricapillus* (Carpenter 1981).

Moore and Koening (1986) and Dunn & Hannon (1989) did not register any nest desertion due to the capture and ringing of flickers *Colaptes sp.* and Magpies respectively, though Imber (1976) found that 10% of the Grey-faced Petrels *Pterodroma macroptera gouldi* he ringed deserted their nests, probably due to handling and observation. Burtt and Tuttle (1983) and Lombardo (1989) recorded the same effect with Tree Swallows *Tachycineta bicolor.* In these three studies birds ringed earlier in the nesting cycle abandoned their clutches more than those ringed later in the nesting cycle. Imber (1976) found that males seemed more prone to desert the nest than females.

A few Slate-coloured Juncos *Junco hyemalis* chicks ringed early in the nesting cycle were removed from the nest by their parents (Smith & Andersen 1982) and the same was observed in Song Sparrows *Zonotrichia melodia* by Lovell (1945).

Little research has been done to study the long-term effects of metal rings on birds. Houston (1974) says that the mortality associated with ringing studies "receives less attention than it deserves". Although metal rings seem to present hazards particularly in very cold or arid regions, the extent to which metal rings may affect survival rates of temperate birds seems to be unknown. The BTO ring recovery files include such records as a Redshank *Tringa totanus* recovered dead 'suspended from a barbed wire fence by its ring'. While the effect of such incidents on survival rates of the ringed component on the population may be slight or trivial, these unquantified biases are generally ignored when ring recovery data are used to assess species population dynamics.

Colour rings

There are not many reports of coloured plastic rings causing adverse effects. Sandhill Cranes *Grus canadensis* pecked at the rings in the first few days (Hoffman 1985) and Magpies did even months after being ringed (Reese 1980). Atherton *et al.* (1984) found that the colour rings they used on doves (Fam. *Columbidae*) constricted and damaged the leg of the birds. They solved this by treating the rings with acetone to seal them. Komen (1987) reported injuries to Cape Gannets' *Sula capensis* feet due to the rings: colour rings slipped down and unwound around the foot constricting the web, sometimes piercing it. Other authors (e.g. Robinson 1985, Strong 1987) did not find any adverse effect when using colour rings.

The effects of colour rings on behaviour are mainly related to the possible interference of the colour of the ring with individual recognition, status signalling, or mate choice. The well-known studies on captive Zebra Finches *Poephila guttata* by Burley showed that male birds wearing red bands were more attractive to females than unringed ones (Burley *et al.* 1982). Birds carrying rings of typical colours of the species (e.g. red) attracted conspecifics while others, carrying colours non-typical of the species (e.g. green), were avoided (Burley *et al.* 1982, 1986a). This in turn affected sex-ratio (Burley 1981, 1986b) and mortality (Burley 1985). Soon after Burley's first paper was published her results were challenged (Immelman *et al.* 1982, Thissen & Martin 1982). Harvey (1986) questioned the results, claiming that they are of great importance but that they should have to be demonstrated under natural conditions.

Watt (1982) evaluated the effect of colour rings on individual recognition in a group of White-crowned Sparrows, not finding any relationship between them. Ratcliffe & Boag (1987) did not find any correlation between ring colour and the Zebra Finch male's ability to gain a female or a nest, but they state that these results "do not falsify Burley's basic finding that Zebra Finches find certain colour bands more attractive than others".

The physical annoyance of the ring can alter the agonistic behaviour of Magpies. Reese (1980) observed how they pecked at their rings repeatedly when unringed birds, under the same circumstances, were hammering their bills against branches or the ground.

Sandhill Cranes marked with colour rings and vinyl flags around standard rings avoided unmarked cranes and these in turn, avoided the marked ones (Wheeler & Lewis 1972).

Beletsky & Orians (1989) made an evaluation of the influence of colour rings on male mortality and reproductive success in Red-winged Blackbirds, failing to find any relationship among rings and these parameters. However, they say that "among species in which males, rather than the resources they control, are the primary basis of mate choice, band colours may be more influential". The results obtained by Brodsky (1988) support this. He found that male Ptarmigans *Lagopus mutus* with red and orange rings gained more mates than those without them. Males with the largest supraorbital combs – a target for sexual selection – get the highest number of mates. Male's mating success can be altered by using rings of a similar colour to that of the supraorbital combs.

Finally, Hagan & Reed (1988) found a lower reproductive success in male Red–cockaded Woodpeckers *Picoides borealis* wearing red colour rings. It did not happen with other colours, and no effect was observed in adult females. Hill & Carr (1989) suggest that this study should not be taken into account as evidence of an effect of colour leg rings. They criticize some aspects of the data collection and the analysis. Hagan & Reed (1989) answered these criticisms and reaffirmed their conclusion.

No correlation between the colours of rings and mortality was found by Hoffman (1985) or Beletsky & Orians (1989). Hagan & Reed (1988) noted that nestling Red–cockaded Woodpeckers with red rings were less likely to be sighted as fledgings.

Other marks attached to the leg

Tape. Colour tape has been used around the leg (Dowing & Marshall 1959, Fankhauser 1964, Johnson 1971) or around leg rings (Gullion 1965, Vestjens 1978). None of the authors make any comment on possible effects of the markers on the birds.

Thread. Oniki (1981) proposed this method to mark nestlings. He found that dull colours were better accepted; red, for instance, attracted the adult's attention. Birds that peer in the nest were seen pecking or pulling at the marks, although they never ejected the young from the nest.

Leg streamers, strips and flags. Many different types of leg tags have been described (Campbell 1960, Thomas & Marburger 1964, Guarino 1968, Royall 1977, Swepston *et al.* 1978 Clark 1979, Goodyear *et al.* 1979). Although most of the authors do not even consider the possible side effects, and Campbell (1960) did not find any, a few problems have been described.

The leg tag has been found to be an excessive drag for Starlings *Sturnus vulgaris* and Red–winged Blackbirds when flying with winds greater than 20 mph. Marked birds were seen to fly behind and below the main flock (Guarino 1968). This author suggests that tags could increase mortality in these species because of shooting by man. Leg streamers can also affect flight in Cranes *Grus grus* (Wheeler & Lewis 1972), as well as their social behaviour. They observed how colour marked birds were avoided by unmarked ones.

Red (or near colours in the spectrum) leg streamers were pecked more often than other colours by Common Grackles *Quiscalus quiscula* (Royall 1977).

Stiles & Wolf (1973), in an evaluation of 2 methods for marking hummingbirds (paint on the back and leg tags), did not observe any change in social behaviour or reproductive activities. Nevertheless, Waser & Calder (1975) reported abnormally loose and flat nests of leg–tagged hummingbirds. Apparently leg tags impaired nest construction and repair.

Dickson *et al.* (1982) evaluated marking techniques for Cardinals. The birds did not show any strong reaction to colour streamers around normal rings, which contrasts with the reaction described by several authors when marking Cardinals with metal rings.

Spottedbacked Weavers *Ploceus cucullatus* marked early in the nesting cycle tended to desert the colony, while those marked late in the nesting season continued their activities (Bruggers 1980).

Willsteed & Fetterolf (1986) used velcro leg tags on gull chicks. The tags were considered not to affect survival.

Flipper bands. Flipper bands have been used on many species of penguin (Sladen & Tickell 1958, Sladen & Penney 1960, Cooper & Mordant 1981, Sallaberry *et al.* 1985). Some feather wear has been reported by Sladen & Penney (1960) and Cooper & Mordant (1981), although in both cases it was slight and did not harm the birds. Nevertheless, Bannash & Oddenig (1981) and Bannash & Lundberg (1984) (both in Sallaberry *et al.* 1985) found that 65% of the birds marked with flipper bands during 1979 and 1980 had wounds by the breeding season of 1981–82. Salaberry *et al.* (1985) present more data on wounded penguins wearing flipper tags and record one case of death due to tags. No consideration seems to have been given to the additional hydrodynamic drag effects that flipper bands may create for swimming penguins.

Web tags. Haramis & Nice (1980) described a method for attaching tags to waterfowl webs, but they did not comment on their effect on the birds. Grice & Rogers (1965) used web tags for marking Wood Ducks *Aix sponsa* ducklings.

A technique to web–tag ducklings in pipped eggs has been described by Alliston (1975). He tested it on 7 species of wild ducks (151 ducklings) and no decrease in hatching success occurred. The process did not affect their survival once they had left the nest.

Others. Toe banding was used by McIntyre (1977) for Great Northern Diver *Gavia immer* chicks. She passed a band through the webbing and around the toe. She notes that the band did not impair movement, have any harmful physical effect, or impede their fledging and survival until the autumn migration.

Wing tags

Adult and juvenile American Coots *Fulica americana* lost weight while wearing patagial tags (Barlett & Rusch 1980). No significant difference in weight between tagged and control birds was found in Band–tailed Pigeons *Columba fasciata* (Curtis *et al.* 1983) or Eastern Willets *Catoptrophorus semipalmatus* (Howe 1980) and no adverse physical effect was observed in raptors and Ravens *Corvus corax* wearing patagial tags (Kochert *et al.* 1983).

Patagial tags did not seem to impair mobility or flight when used on Starlings, Mottled Ducks *Anas fulvigula,* Eastern Willets, Band–tailed Pigeons, egrets or Red Grouse *Lagopus lagopus* scoticus chicks (Hester 1963, Weeks 1972, Boag *et al.* 1975, Howe 1980, Curtis *et al.* 1983, Stiehl 1983, Maddock 1989). Nevertheless, some cranes marked with patagial streamers (Tacha 1979) were reluctant to fly, affecting their migration behaviour.

An initial discomfort has also been described in birds wearing wing marks. This involves frequent preening, body shaking or pecking at the tag for some time after the attachment (Howe 1980, Stiehl 1983, Maddock 1989). For some Ring–billed Gulls *Larus delawarensis* the wing markers were a constant annoyance (Southern & Southern 1983). Knowlton *et al.* (1964) did not observe any discomfort with Turkeys Meleagris gallopavo given wing tags.

Wing tags can cause abrasion of the skin and feather wear (Southern 1971, Mudge & Ferns 1978, Curtis *et al.* 1983, Kochert *et al.* 1983, Hart 1987), although this has not been observed in other studies (Knowlton *et al.* 1964, Hewitt & Austin–Smith 1966, Weeks 1972, Boag *et al.* 1975, Morgenweck & Marshall 1977, Baldasarre *et al.* 1980). Hart (1987) found that using two patagial pins rather than one reduced the amount of feather wear and skin callousing in Herring Gulls *Larus argentatus,* but he also reported three cases of deaths due to wing tags; one bird became entangled with wool around the tag and leg and two trapped primary feathers in the tag fixing pins. Mortality rates for tagged gulls in his study colony were about four times higher than for herring gulls metal ringed at another colony, but breeding success of tagged birds equalled that of unmarked controls in the same colony.

Morgenweck & Marshall (1977) tested the susceptibility to recapture in American Woodcock *Scolopax minor.* No significant difference between wing tagged birds and only ringed birds was found.

Social behaviour can be altered in some species by wing tags. Anderson (1963) observed that 3.4 per cent of the total of tagged Eiders *Somateria mollisima* became solitary. Tacha (1979) also observed this in marked Sandhill Cranes, and those that integrated in a flock were in the lowest levels of the dominance hierarchy. Lockhart & Kochert (1979) documented how Golden Eagles *Aquila chrysaetos* tagged as adults would abandon their territories or be displaced by conspecifics.

Nevertheless, in most of the papers that evaluate or describe a new wing marker or an attachment technique, no effects on behaviour – apart from, in some cases, the initial discomfort described before – have been noted (Hewitt & Smith-Austin 1966, Boag *et al.* 1975, Rowley & Saunders 1980, Howe 1980, Kochert *et al.* 1983, Stiehl 1983). Wallace *et al.* (1980), referring to aggressive behaviour, did not find any difference between tagged and untagged birds.

Although no difference in breeding success was found between wing tagged and ringed birds by Rowley & Saunders (1980), Wallace *et al.* (1980), Kochert *et al.* (1983) or Maddock (1989), some problems that have a negative effect on breeding success have been reported. Golden Eagles tagged as adults can abandon their territories (Lockart & Kochert 1979). Tagged Eiders had a higher rate of nest desertion than ringed ones (Anderson 1963), and Red-winged Blackbirds with wing tags prolonged the interval required to renest (Jackson 1982). Southern & Southern (1983) found that tagged Ring-billed Gulls had smaller broods than ringed ones, but this was not the case in a later study on the same species (Southern & Southern 1985) or for the Willow Ptarmigan *Lagopus lagopus alleni* (Bergerud 1970).

Two long term studies have shown adverse effects of wing tags on the reproductive success of Ring-billed Gulls (Southern & Southern 1985, Kinkel 1989). The results are from one and four years after marking, respectively. In both studies fewer tagged birds returned to the colony site and those that returned arrived later than ringed birds. 60% of the females wearing a wing tag were unable to acquire mates. This did not happen to males. Pair bonds were broken more often when tagged birds were involved. Hatching date was later in tagged birds and a high proportion of them failed to raise any young. Kinkel considers that the tags may interfere in the migration of the birds, as well as having a pronounced long-term effect on their behaviour and reproduction. By contrast, Southern (1971) evaluated a wing tag for the same species and none of these effects were observed.

In one study, the reproductive success of tagged birds (White-tailed Black Cockatoos *Calyptorhynchus funereus*) turned out to be higher than that of untagged ones (Saunders 1982). The authors attribute this result to the age and experience of the birds being different in the two samples.

There have been quite a few studies showing that wing tags may increase mortality (Bolen & Derden 1980, Saunders 1982, Curtis *et al.* 1983). None of the first 29 Eastern Willets marked for Howe's study (Howe 1980), returned to the area the following year (17 had been expected when comparing them with the ringed birds that returned). He suggests that the wing tags may have increased mortality by increasing the drag or by causing abnormal feather replacement during the moult on the wintering grounds. Saunders (1988) obtained a low return rate to the breeding areas of tagged birds: 59% of adult females compared with 100% of unmarked ones. Also immature females that were tagged before fledging had a return rate (4 years later) of 1.3% compared with 12.7% of untagged (ringed) ones.

Szymczak & Ringelman (1986) reported a mortality for tagged female Mallards *Anas platyrhynchos* 15 times that of untagged ones. They observed changes in behaviour of the marked birds that led to changes in the habitat used. The area where they moved was being heavily used by hunters and consequently, the mortality rate increased. If the hunters had not been there, this increase in mortality might not have existed. Bergerud (1970) found equal numbers of marked and unmarked juvenile Willow Ptarmigans shot by hunters.

Anderson (1963), Bergerud (1970) and Rowley & Saunders (1980) found an increase of predation on wing tagged birds. This may be due to the conspicuousness of marked birds or to effects of the marks on the physical condition of the birds (Baldasarre *et al.* 1980). No effect on mortality has been found with wing tagged Red-winged Blackbirds (Cummings 1987) or with Red Grouse chicks (Boag *et al.* 1975).

Havlin (1968) succeeded in fitting miniature wing-tags to ducklings when still in the eggs, during the stage of pipping. He tested the technique on 110 ducklings and coots and reported that the process did not affect the bird's survival.

Back tags

Back tags have been frequently used for game birds (Blank & Ash 1956, Labisky & Mann 1962, Gullion & Marshall 1968, Parker 1981). No physical or behavioural effects were observed by Labisky & Mann (1962) in Pheasants *Phasianus colchicus* (3 died out of 2689). Boag *et al.* (1973) compared the survival of tagged and untagged birds. There was no significant difference between them. Parker (1981) suspected that back tags on nesting Willow Ptarmigan hens might have increased their mortality, although he does not present any data supporting this. Gullion *et al.* (1962) compared the fates of colour ringed Ruffed Grouse *Bonasa umbellus* and back-tagged ones. The latter had a lower chance of survival due to an increased vulnerability to predation. Gullion and Marshall (1968) presented evidence indicating that grey-phase males of this same species marked with back-tags had a lower survival than that of the red-phase. They explain that "the back-tagging made the birds (grey) just as conspicuous as their red-phase brethren, but, because they were inherently less wary, they were taken by predators more readily than the red-phase birds. In these, the conspicuous back-tag did not appreciably alter their chance of survival".

Back tags have also been used in hummingbirds (Baltosser 1978), Blackbirds (Furrer 1977) and young gulls (Cuthbert & Southern 1975). No short-term side effects were observed by Furrer and the chicks did not show any damage to their skin or plumage after the attachment. Some adults removed the tags from their chicks. Although the tags did not seem to attract predators, the authors warn that the possibility of predation should be taken into account when back-tagging birds in an environment where predation is known to occur.

Furrer (1979) described a vertical tag for passerines and he tested it on Starlings and Fieldfares *Turdus pilaris.* The only side effects he observed were some skin abrasion and feather loss that did not seem to affect the birds. The tag did not interfere with flight or affect behaviour.

Neck tags

This technique has been described for gamebirds by Taber (1949), waterfowl by Gullion (1951), pheasants by Nelson (1955) and woodcocks by Westfall & Weeden (1956). It has not been used widely thereafter. An acute tissue reaction to the pin occurred in some American Coots (Gullion 1951). Taber (1949) reported weight loss in Pheasants for a short period after being marked. The marked cocks were successful in establishing territories. He suggests that "cocks do not labour under any important physiological handicap because of being marked", although he warns of the vulnerability to predation of marked birds. No physical or behavioural effects were observed by Westfall & Weeden (1956) in neck tagged Woodcocks.

Neck collars

Neck collars have mainly been used on long-necked waterfowl. Some physical problems have been reported. Ballou & Martin (1964) noted loss of neck feathers when marking Canada Geese *Branta canadensis* with plastic collars, though other authors (Craighead & Stockstad 1956, Maltby 1977, Pirkola & Kalinainen 1984) did not observe any damage to the feathers.

Ankney (1975) suggested that the neckbands worn by Snow Geese *Anser caerulescens* contributed to their death by starvation, although this interpretation has been criticized by Raveling (1976). Some other authors did not detect any physical problem: Lensick (1968), Maltby (1977), Owen (1980), Summers *et al.* (1985).

Canada Geese and Snow Geese have been

seen chewing their collar, and getting their bill stuck in them (Helm 1955, McInnes 1969). Helm (1955) also reported ducks getting their bill stuck in their collars.

As occurs with nasal markers, under severe weather conditions ice can accumulate in the neck collar (McInnes 1969). This can cause the bird's death as reported by Ballou & Martin (1964), Greenwood & Bair (1974) or Zicus *et al.* (1983). These last authors consider that "neckband icing can be a serious mortality factor". They obtained a range of 30% to 68% (for 1979) and 17% to 29% (for 1980) mortality due to neckband icing. Sherwood (1966) and Craven (1979), on the other hand, did not consider this process a significant mortality factor.

An adjustment period may be required by birds fitted with neck collars (Helm 1955). After the attachment, one bird was observed snapping its rubber band repeatedly while preening (Heusmann 1978). On the contrary, Pirkola & Kalinainen (1984) failed to detect any abnormal behaviour.

Although initial adjustment may be required, no long lasting behavioural effects have been found by Helm (1955), Craighead & Stockstad (1956), Ballou & Martin (1964), Maltby (1977), Heusmann (1978), Pirkola & Kalinainen (1984), Johnson & Sibly (1989) or Ely (1990).

Hawkins & Simpson (1985) describe an aggressive reaction against a marked Tundra Swan *Cygnus columbianus* by a conspecific. Eventually, the marked bird flew away and did not go back to the area during that breeding season. Aggressive interactions have also been observed by Neumann (1982). Black-headed Gulls *Larus ridibundus* marked with collars were isolated by other members of the group (unmarked). The author suggests that "acclimatisation to this type of conspicuous behaviour in fellow members of the species, if possible at all, is only so in the long term".

Neckbands can also affect the courtship behaviour in Brent Geese *Branta bernicla* (Abraham & Ankney 1983). The neckbands used could cover the necklace (important in threat displays, which, in turn, establish the rank of competing birds) or increase the amount of white – contrast – on the bird's neck. If the pattern of the bird's neck is important in mate choice or in individual recognition, the band could interfere in these processes. The authors point out that, eventually, these problems can make marked birds have lower productivity than unmarked ones because they would have lower success in agonistic encounters. In fact, Lensick (1968) found that Black Brant *Branta bernicla nigricans* with neckbands had a significantly lower nesting success than that of leg ringed controls or unmarked birds.

In other geese (Sherwood 1966, Chabrec & Shoer 1975, McInnes & Dunn 1988) and in American Coots (Barlett & Rusch 1980), no effect on reproductive success has been observed. Johnson & Sibly (1989) reported a tendency for collared Geese to have a higher breeding success than uncollared ones, but they think this can be attributed to the greater age and experience of collared individuals in their sample.

Heusmann (1978) considered that the presence of collars on nesting Wood Ducks could have been the cause of nest abandonment.

Another important mortality factor can be the selection by hunters of marked individuals (Craven 1979), although McInnes & Dunn (1988) found the opposite result working on geese as well. Heusmann (1978) did not find differences in survival indices between marked and unmarked Wood Ducks. Barlett & Rusch (1980) found a difference in duck survival, but they attributed it to the method used. Finally, McInnes & Dunn (1988) suggest that the lower frequency of capturing neckbanded geese on the nesting grounds (compared with that of leg ringed individuals), could result from increased mortality, or emigration of neck banded geese.

Nasal marks

Nasal discs and saddles have mainly been used for ducks and geese. No physical or behavioural effect has been found on Shovelers *Anas clypeata* (Sugden & Poston

1968), Canada Geese (Raveling 1969), Marabou Storks *Leptoptilos crumeniferus* (Pomeroy 1975), Mallards (Byers & Montgomery 1981) or Barrow's Goldeneyes *Bucephala islandica* (Savard 1988).

Most of the problems reported are generally physical. One of these is the entanglement of the marking device (Evrard 1986), which can cause injuries to the bird's nostril (Sherwood 1966) or its death (Lee 1960). Nevertheless, this has not been reported in most of the studies using nasal markers.

Erskine (in Bartonek & Dane 1964) considered that caution was necessary in using nasal discs for diving ducks, but Bartonek & Dane themselves did not find any impairment of diving ducks wearing nasal discs.

Under severe winter conditions, ice accumulated on the nasal marks can have negative effects (Byers 1987). He reports that 2 to 32% of Mallards developed ice on their nasal saddles; the figure was correlated with windchill conditions. The weight of the ice on the mark can be high enough to cause the death of the animal (Greewood & Bair 1974), although birds appeared able to de-ice the nasal saddles in most instances.

Difficulty in dislodging leeches from the nares when wearing a nasal saddle has been seen in Teals *Anas crecca* by McKinney & Derrickson (1979). The birds increased the time spent scratching, more during feeding (when the leeches enter the nares), than during preening or resting. Apart from this increase in scratching, they did not observe any other behavioural abnormality.

Some discomfort has been reported following the attachment of the mark, though after a short period the birds got used to them and behaved apparently normally (Lee 1960). Thus, Bartonek & Dane (1964) observed Blue-winged Teals *Anas discors* dipping their bills into the water and forcing the air out through their nostrils, occasionally shaking their heads, or their nasal discs being pecked by other individuals. Koob (1981) observed that Ruddy Ducks *Oxyura jamaicensis* wearing nasal saddles spent more time in maintenance activities and less in locomotory ones. These birds suffered from behavioural differences as well. The marked birds were less successful in obtaining mates than unmarked ones. Female Ruddy Ducks seemed to prefer males without the mark. Five males that were paired previously to the attachment of the saddle, lost their mates to unsaddled males within 2 hours. The author suggests that these effects may be due to the Ruddy Duck being a small species, and that this does not necessarily happen in bigger duck species. For instance, Lee (1960) followed the breeding of Canada Geese marked with nasal markers and did not observe any apparent effect on their breeding behaviour. Also Bartonek & Dane (1964) did not detect any effect on pair formation of Blue-winged Teals with nasal discs.

Reproductive success was not affected in Canada Geese (Lee 1960), Long-tailed Ducks *Clangula hyemalis* (Alison 1975) or Pacific Black Ducks *Anas superciliosa,* Grey Teals *Anas gibberifrons* and Chestnut Teal *Anas castanea* (Davey & Fullagar 1985), although Doty & Lee (1974) found a lower success (83%) in Mallards in the year of attachment of the mark than in subsequent years (90%).

Bartonek & Dane (1964) found no significant difference in mortality between marked and unmarked birds, though Erskine (in Bartonek & Dane 1964) found that, after a year, sawbills *Mergus spp.* marked with nasal discs had a recovery rate less than half of that for untagged ringed birds, suggesting a high mortality of birds with nasal discs in the first months after marking.

Dyes

Dyes can be very useful, not only to provide individual or group markings, but also to increase recovery rates. Handel & Gill (1983) estimated that Western Sandpipers *Calidris mauri* that had been dyed yellow were about 16 times more likely to be seen by observers than birds that had only been colour ringed. However, dyes can cause an initial discomfort. Birds may spend much time preening the painted feathers (Moffitt 1942, Swank 1952, Stiles & Wolf 1973, Dickson *et al.* 1982). It is well known that dyes in organic solvents present a potential risk to birds from solvent fumes, so that good ventilation is important while dyes dry. No research seems to have been done to assess any influence of dye-marking on aerodynamic drag of birds, or on buoyancy of waterfowl or seabirds after application of dyes. Anecdotal evidence suggests that picric dye, or alcohol used as a solvent, or physical disturbance to the body plumage may cause ducks to sink in water, at least if they enter water before preening, as is usually the case when waterfowl or seabirds are released after dye-marking (R.W. Furness pers. obs. of Goosanders *Mergus merganser,* Eiders, Fulmars *Fulmarus glacialis* and auks).

The main problem caused by dyes seems to be the consequences of colour change. Bennet (1939), working with captive doves, noted changes in the behaviour of marked birds. The social hierarchy of the flock was upset by the colouring of some individuals. Neumann (1982, 1985) has presented evidence of how dyeing feathers can alter social behaviour in Black-headed Gulls. Marked birds were attacked by conspecifics, and were isolated. The time it took before the bird reintegrated into the group, and the degree of violence of the attacks, varied with different markings. A gull extensively painted in pink was still being attacked 11 days after marking it (Neumann 1982).

Raveling (1969) used dyes on Canada Geese and did not observe any social rejection of the marked individuals. The same was reported by White *et al.* (1980) marking Blackbirds and Starlings, and by Brown & Brown (1988) marking Cliff Swallows *Hirundo pyrrhonota.*

In a few studies, important impacts on reproductive success have been documented. Noble (1963) painted male moustache markings on female Flickers, affecting sex recognition. Oystercatchers *Haematopus ostralegus* copulated more often after marking compared to normal conditions (Neumann 1985). The use of yellow markers on females Mourning Doves' *Zenaida macroura* heads altered pair bonds (Frankel & Baskett 1963). Once the nesting stage had started, marked Black-headed Gulls abandoned their nests or brood more frequently than their non-marked partners: ringed birds without dyed feathers were used as controls, so this side effect is not the result of capturing and handling, but of the colour marking (Neumann 1985).

In Tree Swallows, female subadults had the same probability as female adults of deserting after being ringed and having their feathers dyed. Other authors have also failed to find a higher nest desertion rate among birds with their feathers dyed (Mossman 1960, Paton & Planck 1986, Rodgers 1986, Reynolds 1987).

Dyes have also been used for Red-winged Blackbird chicks (Haigh 1968), Hen Harrier *Circus cyaneus* chicks (Picozzi 1980) and egret chicks (Ploger & Mock 1986). The relationship among siblings or between the chicks and their parents was not upset by the colour marks.

A technique for dying embryos has been used by Evans (1951) and Rotterman & Monnett (1984). In neither of the studies was the embryo mortality increased significantly. Rotterman & Monnett weighed the marked and unmarked nestlings, not finding any significant difference between groups. The same result was obtained when considering the probability of predation during the nestling stage. In spite of these results, the authors consider that this does not necessarily happen in other birds. So, it should be borne in mind that nestlings marked with certain colours might be rejected, and that an increase in conspicuousness could attract some predators. The latter was reported by Eklund (1961) who showed that dye-marked downy South Polar Skua *Catharacta maccormicki* chicks were more likely to be eaten by predators (conspecifics) than were naturally-coloured chicks.

Other marks

Adhesive tags on the bird's head have been used on Mourning Doves (Goforth & Baskett 1965) and on nestling Pied Flycatchers *Ficedula hypoleuca* (Gottlander 1987). Pair bonds were disrupted when using yellow markers on female Mourning Doves' heads during the first attempts to incubate. They did not observe any effect on male's behaviour or in either sex when they used other colours or other locations for the markers. No changes in behaviour were observed by Gottlander.

Yellow markers on Pheasants seemed to attract predators, and more birds were killed when wearing yellow markers than other colours (Kessler 1964).

Poncho markers have been used for game birds. They can interfere with the air exchange in displaying male Sage Grouse *Centrocercus urophasianus* (Pyrah 1970) or contribute to the mortality of the birds (1–2%) when they get their bill stuck into the poncho (Biadi 1973). He also observed that the poncho was an impediment when the birds wanted to put their head under the wing to sleep, and birds became stuck in bushes or wire nets.

Wright (1939) described a marking technique by imping feathers. This has been used to colour mark birds, adding coloured feathers to the bird's feathers (Bendell & Fowle 1950), and to make the bird's feathers longer (Andersson 1982). Andersson's study of Widowbirds *Euplectes sp.* showed that individuals with longer tails can increase their breeding success at the expense of normal ones because they are preferred by females.

Heydweiller (1934), Edminster (1938) and Leopold *et al.* (1938) attached a bright coloured feather to a birds' tail feather. Tripensee (1941), Ritchison (1984) and Best (1990) used a similar method but, instead of attaching a feather, they attached a tag or tape. The last author did not observe any side effect. The others do not make any comment on the possible effects of the markers on the birds, either in terms of aerodynamic drag (which might be considerable) or of influences on mate choice.

Data loggers

In this section we consider different data logging devices and their effects on birds. Various recorders have been used on Adélie *Pygoscelis adeliae* and Jackass *Sphenicus demersus* Penguins and some negative effects of these and of human disturbance have been reported in detail by Wilson & Wilson (1989a, 1989b), Wilson *et al.* (1989, 1990, 1991). Wilson *et al.* (1989) describe a method to determine the number of pecks directed to devices as a measure of abnormal behaviour due to it. They used this to determine which package colour was best accepted by Adélie Penguins (Wilson *et al.* 1990) and to assess the effect of attaching devices of different size (Wilson *et al.* 1989). Culik & Wilson (1991) tested the effects of implanted and external instruments on the swimming performance and energy consumption of Adélie Penguins, showing that both systems have a pronounced negative effect on the variables measured, and reviewing the likely effects of similar packages used in other studies.

Altimeters. A device attached to the bird's back for measuring flight altitude was described by Gustafson *et al.* (1973). It has been used on homing Pigeons & Swifts *Apus apus* (Gustafson *et al.* 1973, 1977, Kristiansson *et al.* 1977). The effects of the device on the birds, if any, are not described in these papers.

Activity recorders. Lefebvre *et al.* (1967) developed a device to measure the time spent in flight by birds, but they did not test it on free–flying birds. An activity recorder based on it was used by Prince & Francis (1984) to study the foraging activity budgets of Grey headed Albatrosses *Diomedea chrysostoma.* There are no comments on possible effects on the birds in either of these papers.

A different activity recorder for measuring attentiveness to the nest was described by Morris & Hunter (1976). They found no significant difference in parental behaviour of experimental and control birds.

Electronic activity recorders based on watches have been described by Cairns *et al.* (1987a, 1987b) and tested on Guillemots *Uria aalge* and Gannets *Sula bassana.* The device did not seem to affect the birds' locomotor activities or their behaviour. Cairns *et al.* (1987a) warn that "instruments carried by pursuit diving animals may alter diving ability through hydrodynamic drag". Cairns *et al.* (1987b) estimated that the instrument they were using increased the costs of flight by 6%, requiring a consumption of 11% of the available surplus power, but did not quantify additional costs of swimming.

Gales *et al.* (1990) used electronic activity recorders to study the foraging behaviour of the Little Penguin *Eudyptula minor.* They found that tagged birds had a significantly lower water influx and metabolic rates. Foraging efficiency decreased even when small attachments were used. Anderson *et al.* (1991) describe a miniature recorder to study plunge–diving seabirds, but they do not consider its possible effects.

Wilson & Wilson (1988) used a remote–sensing device that gave information on swimming speed and heading of the birds. Nine Jackass Penguins were tagged and all of them returned in good condition.

Distance meters. A distance meter for large marine animals was described by Wilson & Achleitner (1985), and its effects are considered by Wilson *et al.* (1986).

Depth recorders. Different kinds of depth recorders have been described by Kooyman *et al.* (1983) for marine birds and mammals, Wilson & Bain (1984a) for penguins and Montage (1985) for Little Penguins. These devices have mostly been used on penguins: Kooyman *et al.* (1971, 1982), Adams & Brown (1983), Lishman *et al.* (1983), but also for Puffins *Fratercula arctica,* Shags *Phalacrocorax aristotelis,* Razorbills *Alca torda,* Common and Brunnich's Guillemots *Uria lomvia* (Burger and Simpson 1986, Barrett & Furness 1990, Wanless *et al.* 1991).

The depth gauges described by Wilson & Bain (1984) were tested by the authors on 32 penguins which seemed unaffected by the device. It has been assessed by Burger & Wilson (1988) and used by Barrett and Furness (1990). Wanless *et al.* (1991) used depth gauges for studying diving depths of Shags and they considered that the cross–sectional area of the gauges would have little effect on the diving behaviour. They consider that the small size of the gauges avoids some problems associated with larger devices.

Croxall *et al.* (1988) compared the mass of prey taken ashore by tagged and untagged Gentoo Penguins *Pygoscelis papua* and Macaroni Penguins *Eudyptes chrysolophus,* and did not find a significant difference between them. They estimated that the cross–sectional area of the depth histogram recorder they used would reduce travelling speed by 9% (5%–6% in the larger Gentoo Penguins).

Speed meters. Wilson & Bain (1984b) described a speed meter for penguins at sea. The device was tested on 25 birds and no apparent adverse effect was observed. Speed meters have also been used on penguins by Nagy *et al.* (1984) and Adams *et al.* (1988).

Wilson *et al.* (1986) used speed meters to test the effect of recording devices on the foraging performance of Jackass Penguins, showing that the recorders significantly reduced swimming speed. They pointed out the need to alter streamlining as little as possible by keeping the device volume and cross–sectional area to a minimum. The same result was obtained for Gentoo and Adélie Penguins (Wilson *et al.* 1989).

Radio transmitters

Kenward (1987) reviewed different attachment methods and their effects on birds. Other papers deal with telemetric technique for animals in general (Tester 1971, Macdonald & Amlaner 1980, Cheeseman & Mitson 1982, Mech 1983) for birds (Marion & Shamis 1977), grouse (Lance & Watson 1978), owls (Nicholls & Fuller 1987) and galliformes (Hill & Robertson 1987).

In Table 2 we have summarized the different adverse effects reported in the 187 papers reviewed for this section. For each one we give the number of papers where the effect has been found, the number in which it is specifically said that it has not been found, and those in which the effects are not considered. 24% of the papers do not consider any possible deleterious effects of the package.

Many of the papers that comment on general behaviour or physical condition do not find adverse effects (Giroux *et al.* 1990, Hill & Talent 1990). The most reported effect is an initial discomfort (Dwyer 1972, Dumke & Pils 1973, Nenno & Healy 1979, van Dyke 1981,

Table 2. Effects of radio transmitters on birds as indicated in 171 papers published in Auk, Ibis, Journal of Applied Ecology, Journal of Wildlife Management and Ornis Scandinavica.

Effects	*Some effects*	*No effects*	*Not reported*
Initial discomfort	28	4	155
Injuries	3	7	177
Feather wear/loss	6	1	180
Weight loss	3	5	179
Transmitter drag	12	1	174
Locomotion	8	16	163
Aerial or transmitter removed/broken	6	1	180
Mandible caught in neck–collar/harness	3	0	184
Effect of harness	6	1	180
Dispersal	0	1	186
Habitat use/choice	0	5	182
General behavioural/physical effects	10	41	136
Foraging behaviour	8	6	173
Reproductive behaviour	8	18	161
Reproductive Success	4	12	171
Brood size	0	2	185
Nest/brood desertion	5	1	181
Growth rate	1	3	183
Metabolic rate	2	0	185
Survival	14	13	160
Predation	7	3	177
Survival+predation	21	16	150

Perry *et al.* 1981, Johnson & Caslick 1982, Iverson *et al.* 1985, Watson 1985, Kirby & Cowardin 1986) that can last from a few minutes (Smith & Gilbert 1981) up to a few weeks (Siegfried *et al.* 1977), though usually the birds recovered normal activity 2 to 7 days after attachment. This discomfort is mainly shown as an increase in preening activity and pulling at the device. The device can be such an annoyance for some birds that they may end up breaking part of it or even removing it (Raim 1978, Morris & Black 1980, Perry 1981, Slaugh *et al.* 1989, Sorenson 1989). It can affect locomotion (Graber & Wunderle 1966, Greenwood & Sargeant 1973, Bray *et al.* 1975, Smith *et al.* 1983), food consumption (Boag 1972) or display (Hirons & Owen 1982).

Other physical problems include skin abrasion due to the attachment, feather wear or loss, external and internal injuries, impairment of movement, and weight loss (Appendix 1).

To minimize bias it has been suggested that transmitters should weigh less than 5% of the weight of a small bird (Hill & Robertson 1987), and a smaller percentage for large birds (Hedin & Caccamise 1982, Caccamise & Hedin 1985). However, Pennycuick *et al.* (1989) suggest that the acceptable radio mass for birds should be expressed as a fraction of the food load mass they can carry, not as a percentage of the body mass.

Gessaman & Nagy (1988) calculated the metabolic rate of homing Pigeons *Columba livia* during long distance flights and found that the birds produced 90% more carbon dioxide when fitted with a transmitter and harness weighing less than 5% of the bird's body weight. The flight speed was 15% slower when covering a distance of 90 km with a transmitter attached by glue, and more than 31% slower when wearing a transmitter fitted by a harness. An experiment carried out in a wind tunnel by Obtrecht *et al.* (1988) showed how radio transmitters can increase the drag of the bird. Nevertheless, Sedinger *et al.* (1990) did not find any effect of transmitters on Black Brant energy expenditure or on changes in body mass.

Transmitters can alter the bird's breeding behaviour or their breeding success (Amlaner *et al.* 1978), though many authors have not reported any such effects. As with other markers, the time of capturing and marking during the reproductive cycle can cause different effects. Kuck et al. (1970) and Wanless *et al.* (1985) found that birds were more prone to desert their nests when trapped and fitted with a transmitter when laying or incubating, while this rarely occurred later in the breeding cycle.

Only a few authors have looked at the brood size of equipped birds and the growth rates of their chicks. Pennycuick *et al.* (1989) suggest that the weight of the radio transmitter may affect the chick's growth rate by a reduction of prey delivered by their parents. Radio–tagged Guillemots and Razorbills *Alca torda* brought fewer fish to their chicks (Wanless *et al.* 1988a, 1988b), returned more often without a prey for their chicks, made longer foraging trips than those of control birds (Wanless *et al.* 1989, 1990). Swallows *Hirundo rustica* also made fewer but longer foraging trips when attached with a radio transmitter (Brigham 1989).

Survival can be reduced due to the weight of the transmitter or the method of attachment method (Hessler *et al.* 1970, Johnson & Berner 1980, Hirons and Owens 1982, Angelstam 1984, Small & Rusch 1985, Pekins 1988, Conroy *et al.* 1989, Eberhard *et al.* 1989, Marcström *et al.* 1989, Slaugh *et al.* 1989, Sorenson 1989). In some cases authors have demonstrated an increased vulnerability to predation (Hessler *et al.* 1970, Erikstad 1979, Odom *et al.* 1982, Marks & Marks 1987) or to hunting (Schultz *et al.* 1988).

DISCUSSION

This long review has found many examples of marks and devices influencing the behaviour of birds, and in some cases reducing their survival rates. It would be wrong to suggest that these examples should be used to argue against marking of birds. There are, of course, tens of thousands of scientific studies where no such effects appear to have occurred. We ourselves use rings, colour rings, dyes, depth recorders, radio transmitters and other devices on birds and we believe that in the vast majority of studies using such methods biases in the data and hazards to the birds are negligible.

However, this review shows that marking techniques may have a wide range of effects on birds, from a short term discomfort to effects on breeding and survival. Some general points seem to emerge. For example, hydrodynamic drag is more critical than mass when designing devices to study diving behaviour of penguins, harnesses cause more problems in radio telemetry studies than attachment to feathers, wing tags are particularly problematical on migratory birds, and so on. In many cases it has been possible to reduce harmful effects by careful design of the mark, in terms of its hydrodynamic drag, its colour, position of attachment, mass, season of application and so on. It is obviously to the benefit of researchers, as well as the birds they study, if marking can be done in a way that minimizes the risk of altering ther normal behaviour and ecology of birds. We consider it is desirable that bodies regulating marking of birds should encourage research specifically to assess effects of marks and devices; such work could readily be carried out in association with current research programmes. For example, professional researchers may use dyes on seabirds to study their foraging ranges from a colony but it would be appropriate for an adjunct study to be set up into the time budgets and social interactions of dye–marked individuals compared to controls, making use of the same marked birds. A greater body of detailed data collected with the specific aim of testing for effects of marks would improve confidence in the suitability of these techniques for bird research.

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APPENDIX

Reported effects of radio transmitters on birds

General (initial discomfort not included)

Alonso et al. 1987, Amstrup 1980, Anderson & Ricklefs 1987, Anglestam 1984, Archibal 1975, Brander 1968, Bray et al. 1975, Cochran 1972, Cochran et al. 1967, Diehl et al. 1986, Dumke & Pils 1073, Dunstan 1972, Dwyer 1972, East & Hofer 1986, Enderson & Kirven 1983, Erikstad 1979, Fuller & Tester 1973, Gilmer 1974, Heath 1987, Herzog & Boag 1978, Hessler et al. 1970, Hines & Zwickel 1985, Hirons 1980, Hudgins et al. 1985, Jordan 1988, Karl & Clout 1987, Kenward 1978, Lance 1970, Marshall & Kupa 1963, Martin 1978, Maxon 1978, McCrary 1981, Melvin et al. 1983, Nenno & Healy 1979, Nesbitt et al. 1982, Nicholls & Barner 1968, Nicholls & Warner 1972, Perry et al. 1981, Raim 1978, Rohwer 1985, Sayre et al. 1981, Slaugh et al. 1989, Smith & Gilbert 1981, Snyder et al. 1989, Wanless et al. 1988b, Watson 1985, Ward et al. 1986, Widen 1982, Wilson et al. 1989b.

Initial discomfort
Amlaner et al. 1978, Boag 1972, Bray & Corner 1972, Bray et al. 1975, Diehl 1986, Dufty 1982, Dumke & Pils 1973, Dwyer 1972, Dyke 1981, Gilmer 1974, Graber & Wunderle 1966, Greenwood & Sargeant 1973, Hirons & Owens 1982, Iverson et al. 1985, Johnson & Caslik 1982, Kirby & Cowardin 1986, McCrary 1981, Morris & Black 1980, Nenno & Healy 1979, Perry 1981, Perry et al. 1981, Raim 1978, Schultz et al. 1988, Siegfreid et al. 1977, Smith & Gilbert 1981, Smith et al. 1983, Sorenson 1989, Watson 1985, Williams 1974, Wooley & Owen 1978.

Skin abrasion/injuries/feather wear/feather loss
Amstrup 1980, Anderson & Ricklefs 1987, Diehl 1986, Gilmer 1974, Greenwood & Sargeant 1973, Hessler et al. 1970, Hines & Zwickel 1985, McCrary 1981, Nicholls & Warner 1968, Nicholls & Warner 1972, Pekins 1988, Perry 1981, Wanless et al. 1985.

Weight loss
Diehl et al. 1986, Erikstad 1979, Greenwood & Sargeant 1973, Johnson & Berner 1980, Kenward 1978, Perry 1981, Raim 1978, Royall & Bray 1980.

Aerial/transmitter removal or broken by birds
Karl & Clout 1987, Morris & Black 1980, Raim 1978, Royall & Bray 1980, Slaugh et al. 1989, Sorenson 1989, Watson 1985.

Mandible caught in neck radio collar/harness
Hirons & Owen 1982, Sorenson 1989, Wallestad & Schladweiler 1974.

Effect of harness
Heath et al. 1989, Hessler et al. 1970, Hines & Zwickel 1985, Hirons & Owen 1982, Kenward 1985, Kenward et al. 1982, Slaugh et al. 1989.

Transmitter weight – drag
Amlaner et al. 1978, Caccamise & Hedin 1985, Hedin & Caccamise 1982, Hill & Robertson 1987, Johnson & Berner 1980, Michener & Walcott 1966, Nesbitt et al. 1978, Obrecht et al. 1988, Pennycuick & Fuller 1987, Pennycuick et al. 1989, Slagle 1965, Sibly & McCleery 1980, Snyder 1985, Warner & Etter 1983.

Locomotion
Diehl 1986, Dufty 1982, Dwyer 1972, Dunstan 1972, Greenwood & Sargeant 1973, Heath et al. 1989, Herzog & Boag 1978, Hessler et al. 1970, Jackson et al. 1977, Jordan 1988, Lord et al. 1962, Marks & Marks 1987, Melvin et al. 1983, Michener & Walcott 1966, Morton 1989, Owen & Morgan 1975, Pekins 1988, Perry 1981, Raim 1978, Royall & Bray 1980, Schultz et al. 1988, Slagle 1965, Woakes & Butler 1984.

Habitat choice/use
Boag 1972, Dwyer 1972, Gilmer 1974, McCrary 1981, Siegfreid et al. 1977.

Foraging behaviour
Anderson & Ricklefs 1987, Boag 1972, Brigham 1989, Jackson et al. 1977, Karl & Clout 1987, Massey et al. 1988, Nesbitt et al. 1982, Pennycuick et al. 1989, Perry 1981, Siegfreid et al. 1977, Swanson et al. 1976, Wanless et al. 1988a, Wanless et al. 1988b, Wanless et al. 1991.

Metabolic rate/enegetic costs
Hedin & Caccamise 1982, Gessaman & Nagy 1988, Obrecht et al.1988, Sedinger et al. 1990.

Breeding ecology
1.Breeding behaviour.
Amlaner et al. 1978, Archibal 1975, Brander 1968, Dwyer 1972, Gilmer 1974, Herzog & Boag 1978, Hirons 1980, Jordan 1988, Kls et al. 1989, Karl & Clout 1987, Lance 1970, Morris et al. 1981, Nesbitt et al. 1978, Raim 1978, Ramaka 1972, Sayre et al. 1981, Siegfreid et al. 1977, Smith & Gilbert 1981, Sorenson 1989, Wallestad & Schladweiler 1974, Wanless et al. 1985, Wanless et al. 1988b, Wanless et al. 1990, Wanless et al. 1991, Ward et al. 1986, Wegge & Larsen 1987.
2.Breeding success.
Amlaner et al. 1978, Ball et al. 1975, Enderson & Kirven 1983, Erikstad 1979, Green 1984, Hines & Zwickel 1985, Johnson 1971, Karl & Clout 1987, McCrary 1981, Massey et al. 1988, Pennycuik et al. 1989, Sibly & McCleery 1980, Taylor 1991, Wanless et al. 1988a, Wanless et al. 1988b, Wanless et al. 1989, Wanless et al. 1990, Wanless et al. 1991, Warner & Etter 1983.
3.Nest/Brood desertion.
Kuck et al. 1970, Horton & Causey 1984, Massey et al. 1988, Wallestad & Schladweiler 1974, Wanless et al. 1985, Ward et al. 1986.

Predation
Erikstad 1979, Hessler et al. 1970, Horton & Causey 1981, Marks & Marks 1987, McEwen & Brown 1966, Odom et al. 1982, Rappole et al. 1989, Siegfreid et al. 1977, Slaugh et al. 1989, Sorenson 1989.

Survival
Anglestam 1984, Conroy et al. 1989, Eberhardt et al. 1989, Erikstadt 1979, Herzog 1979, Hessler et al. 1970, Hines & Zwickel 1985, Hirons & Owen 1982, Horton & Causey 1981, Johnson 1971, Johnson & Berner 1980, Kirby & Cowardin 1986, Lance 1978, Marcström et al. 1989, Morris et al. 1981, Pekins 1988, Ringleman & Longcore 1982, Schladweiler & Tester 1972, Schultz et al. 1988, Slaugh et al. 1989, Small & Rusch 1985, Snyder 1985, Snyder et al. 1989, Sorenson 1989, Speake et al. 1985, Warner & Etter 1983, Wegge & Larsen 1987, Wiley & Causey 1987.

APPENDIX 2

-SITE SELECTION OF THE COLLARED PRATINCOLE *GLAREOLA PRATINCOLA* IN PROVINCE OF SEVILLA, SPAIN

vo & L.J.Alberto

UCTION

ost aspects the Collared Pratincole
la pratincola is a little known species;
en population sizes are accurately known.
iggest population in Europe occurs in
and was estimated at 10 000-15 000 pairs
and Simmons 1983), although there have
only partial counts (Martinez Vilalta
On the other hand, it is widely
ized that there has been a decrease in
s in recent years, mainly because of
t loss (Otero 1980, Cramp and Simmons
Martinez Vilalta 1985, Fernandez Cruz
The Collared Pratincole is thus
ered as a "vulnerable" species in the
ed Data Book.

Collared Pratincoles in the Iberian
ula occur in the south-west specifically
he Guadalquivir marshes and their
ndings (Valverde 1960, Cramp and Simmons
Over 70% of this area has been turned
gricultural land (Sanchez *et al.* 1977),
he process is continuing in remaining
It seems that this habitat change has
ed the Collared Pratincole population, as
happened in some other species (e.g.
ith 1987). For this reason, we are
ting to estimate the population size and
dy habitat selection and reproductive
s to establish, among other things, the
auses of the population decrease, and to
necessary measures to protect this
s.

paper analyses the establishment of
es in relation to biotopes, and estimates
opulation in the province of Sevilla,
rather little has been published on the
y of Collared Pratincole (Feeny 1960,
1960, GEA 1985).

ON AND METHODS

ovince of Sevilla was selected because
colonies occur there. The area of the
National Park (about 20% of the
ce) in Sevilla, was excluded (Figure 1).
emaining open areas of the province
0 000 ha) were explored. Previously we
d out a study of wetlands loss in the
ce since 1918 that was of great help in
ng farmlands which had previously been
d, and which were often occupied by
ng colonies in 1989.

es were located by driving through the
fields. Lowlands and farmland near water
as channels, streams, lagoons and
ary pools, were searched intensively.
es were counted during May and the first
of June 1989, this being the best period
imate the number of birds present; prior
is period there is some nomadism of
duals and, after this period, there are
les that can be counted as adults.

haracteristics of the biotope where each
was found were recorded and assigned to
three types:

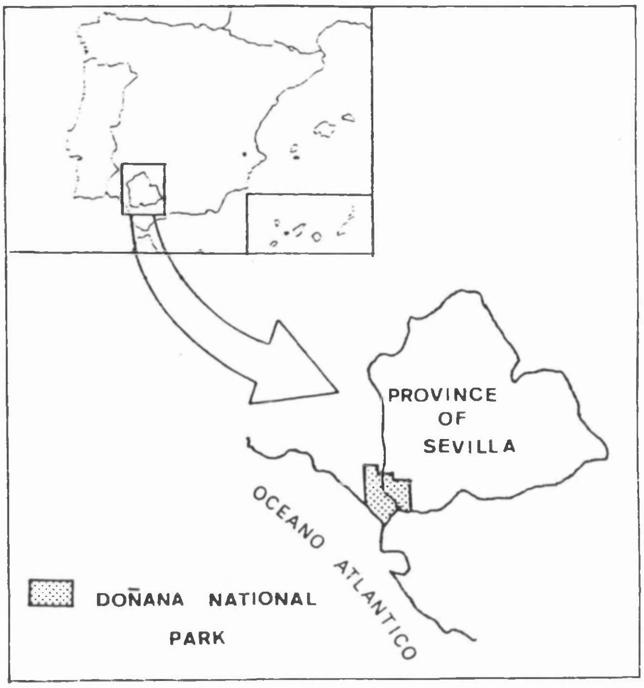

Figure 1. The location of the study area in south-western Spain.

A) <u>Marshes</u>
Areas having the typical marsh characteristics, including some places with minor human influence. In most cases these marshes are remains of previously much more extensive marshes that had been partially drained for agriculture.

B) <u>Fallow lands</u>
Fields devoted to crops but not seeded, or seeded fields in which, at the time of the establishment of the colony, plants could not yet be seen.

C) <u>Crops</u>
Cultivated fields in which, at the time of colony establishment, plants were present, normally with a height of *c.* 10 cm.

The following difficulties were encountered when counting in the breeding colonies:

1) Counting from outside the colony under-estimated the true number of individuals because birds could not be seen on the ground. It was necessary to enter the colony in order to flush birds.
2) In big colonies, only birds close to the intruder took off. It was necessary to have a second person to compare these counts with counts made from outside the colony.
3) At certain times of the day and with certain atmospheric conditions, some individuals foraged away from the colony. Such counts under-estimated the real number.

Table 1. Distribution of colonies and birds in the three habitats described.

	Marshes	Fallows	Crops	Total
No of Colonies	22	30	6	58
%	37.9	51.7	10.4	
No of birds	1 550	1 912	229	3 691
%	42.0	51.8	6.2	
Mean Birds/Colony	70.5	63.7	38.2	
S	53.5	72.3	13.9	
C	75.9	113.4	36.4	

se reasons, the counts were carried out
ully selected times by two counters,
of them walking through the colony.

AND DISCUSSION

the results refer to breeding
, the numbers of individuals, not of
are given. It is not known whether
occurs and/or whether immature birds
ere.

tribution of colonies over the three
, indicates a strong preference for
lands and marshes. Colonies were scarce
s (Table 1). The average number of
er colony in the three biotopes shows
ces, but they are not statistically
ant.

we do not have detailed data, the area
ow land (type B) in the study area was
n 20 times greater than that of the
Therefore, in comparison with the area
e, it is clear that the Collared
le does not have a preference for
We suggest that fallow land is used as
native to marshes, since almost all the
g marshes over 1 ha hold Collared
le colonies. In contrast, only a small
ge of the fallow lands held colonies.
rds crops, it is evident that they were
ttle used except in very specific
ns (below).

Pratincole established their breeding
unequally over the fallow land and
according to the vegetation (Table 2).
in recently seeded or hardly grown
occurred mostly in cotton and sunflower
and very rarely in sorghum or chickpea
At this time of year, the remaining
uch as wheat, barley or beetroot, had
achieved a height and cover which do not allow the birds to settle there. They also avoided the early planted sunflower fields where the plants had already grown.

In the few cases when Collared Pratincoles selected a crop that had already germinated - mainly sunflowers - there were always the following conditions: plants were never more than 10 cm high and the distance between the lines of plants was at least 75 cm. These features made them similar to other nesting terrains. Perhaps for that reason, the birds sometime selected these crops, even though they would later have to either abandon the colonies altogether or move the colony when the plants grew up. In the latter case, the birds moved to the barren lands, if they existed, where there were no crops or to other open terrain where colonies could continue until the end of the breeding period.

The crops that we include as "fallow lands" are mostly cotton fields (Table 2), and they had not germinated at the time of colony establishment. Therefore, we think that to the Collared Pratincole, they appeared to be the same as uncultivated fields, indeed there is an insignificant difference between the percentages of colonies among seeded and not seeded fallow lands (Table 2).

The 83% of colonies not situated in marshes (Table 2), were established in areas that had previously been either marshes or areas situated near to them. The remaining 17% were established in various locations which were always situated close to existing wetlands or wetlands that had been drained since 1918. We conclude that the species is linked to the location of wetlands even after their disappearance. Nevertheless, it is necessary to obtain more data to know their fidelity to these locations and to understand the implications for the dynamics of the population of Collared Pratincole in Southwest Iberia.

Table 2. Number of colonies in fallow lands and in crops (see text), type of crops, and type of biotope that the current establishments showed in 1989. CT = Cotton; SF = Sunflower; SO = Sorghum; BA = Barren; CP = Chickpea. *Difference not significant, X² test.

	FALLOWS 30					CROPS 6		TOTAL 36
	Not Seeded* 16 (53.3%)	Seeded* 14 (46.7%)						
		CT 10	SF 1	SO 1	BA 2	SF 5	CP 1	
TYPE OF BIOTOPE IN 1918								
Old marshes	14	6	1	1	1	2	1	26 (72.2%)
Pastures near marshes	2	2						4 (11.1%)
Crops						1		1 (2.8%)
Inland wetlands		2			1	2		5 (13.9%)

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AND DISCUSSION

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Inland wetlands		2			1	2		5 (13.9%)

ary, Collared Pratincoles look for big slightly hilled, open areas. In these they establish colonies in unvegetated or where the vegetation is mostly than 15 cm or, where it is higher than has very little cover. Many parts of rshes in the study area met these ns during the time of the colony nt. Since the area of marshes was not nt for the whole Collared Pratincole on, the surplus searched for other o establish colonies. The fallow land major alternative, probably because ered an open terrain. Only seldom did tablish colonies in poorly developed There was also a clear tendency to place in areas that are currently marshes or before.

said before, the losses of natural on the marshes of Guadalquivir river ceeded 70%. In spite of this, the on of Collared Pratincole is still the in Europe. We estimate that from 2 500 0 pairs bred in the province of Sevilla without taking into account those in the area of Donana National Park ongs to this province.

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Dr. J.D. Goss-Custard for correcting y the draft of this article.

ES

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POBLACION NIDIFICANTE DE CANASTERAS *Glareola pratincola* EN LA PROVINCIA DE SEVILLA.

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En 1989 se realizó el primer censo nacional de la población nidificante de, entre otras especies, Canasteras *Glareola pratincola*. Los resultados aparecieron en el número cinco de esta revista (Martínez Vilalta 1991). El autor se pregunta si el alto número obtenido en la provincia de Sevilla (2500 parejas) es normal o si se trata de un suceso extraordinario. El objetivo de esta nota es responder a esta pregunta.

Como parte de un estudio que sobre esta especie estoy llevando a cabo en la provincia de Sevilla, se han realizado censos en los años 1989 (los datos preliminares fueron aportados al censo nacional de dicho año) y 1990. Censos anteriores a éstos sólo existen en el parque Nacional de Doñana pero no en la provincia, de la que, hasta ahora, se desconocía la importacia que tiene para la nidificación de la Canastera.

La mayoría de las colonias están situadas en las marismas del Guadalquivir. Su desecación y puesta en cultivo se ha llevado a cabo principalmente desde los años 50 (Reguera 1983, Cruz-Villalón 1988) y actualmente quedan muy pocas zonas con vegetación de marisma fuera del Parque Nacional de Doñana. La Canastera se asienta en estas zonas (generalmente a lo largo de antiguos brazos del río y a los lados de canales de riego) y en campos de cultivo, principalmente algodón y girasol. Cultivos como remolacha, trigo y otros cereales, con una cobertura de vegetación alta en la época de asentamiento, no son adecuados para la Canastera. Los arrozales (cultivo más abundante en la zona de marismas) permiten el asentamiento, pero todas las colonias formadas en ellos se pierden al comenzar los trabajos de preparación del terreno para plantar arroz. Distintos aspectos de la selección de habitat se discuten en Calvo & Alberto (1990) y en Calvo *et al.* (1993).

Las colonias del interior de la provincia se encuentran principalmente en cultivos en las cercanías de lo que fueron importantes humedales, transformados en terreno agrícola desde los años 60. Algunas lagunas han sido totalmente desecadas aunque en años de fuertes precipitaciones pueden coger agua. Otras van reduciéndose poco a poco y se enfrentan también al problema de colmatación por la erosión de los cultivos que llegan hasta la orilla. Los complejos endorreicos de Utrera y La Lentejuela son los más importantes para la nidificación de la especie en el interior de la provincia de Sevilla, aunque hay colonias dispersas en otras zonas.

La estimación de parejas reproductoras fue aproximadamente igual en 1989 y 1990. En 1991 y 1992 no se censó la población de Canasteras, pero a juzgar por la constancia de los efectivos en colonias seguidas todos los años (1989-1992), el número total no debió diferir de las cifras obtenidas anteriormente. El resultado obtenido en 1989 no es por tanto un suceso extraordinario.

En los años 60 Vielliard (notas de campo 1962-1965) estimó unas 10000 parejas en toda la zona de marsismas del Guadalquivir. Aunque no existan censos continuados, la población ha sufrido un claro declive, y colonias en lugares tradicionales de nidificación han terminado desapareciendo. Esta tendencia es la misma en otras áreas de cría en Europa (Uhlig 1989, Nadler 1990). En vista de la importancia internacional de la zona (suroeste de España en general) para la cría de la Canastera sería deseable un seguimiento más cercano de la población nidificante en este área así como un mayor interés por parte de los organismos competentes en el estudio y conservación de esta especie.

Tabla 1 - Estimación del número de parejas reproductoras de Canastera en 1989 y 1900 en la provincia de Sevilla (Parque Nacional de Doñana no incluido). Porcentaje de parejas en zonas del interior de la provincia y en el área de las marismas del Guadalquivir.

	1989	1990
Estimación de parejas reproductoras	2500-3000	2750-3000
% en zonas del interior	6%	8%
% en zona de marismas	94%	92%

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