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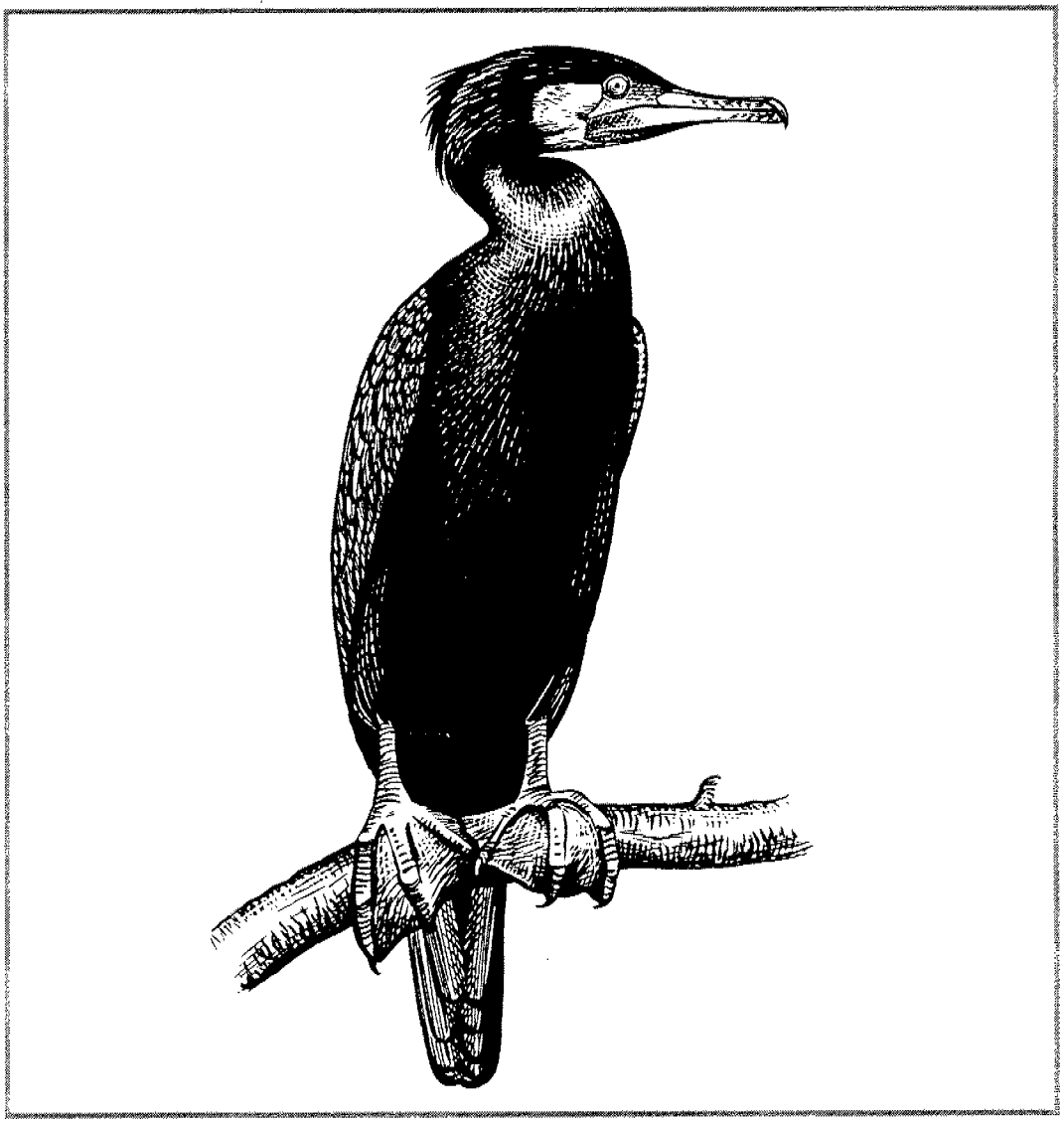

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Movements and distribution of inland breeding cormorants in England

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Summary

Numbers of cormorants *Phalacrocorax carbo* breeding inland in England have increased markedly over the past 18 years. Since first breeding inland at Abberton Reservoir, Essex, in 1981, numbers have increased at a mean of 35% per year to reach 1,437 pairs at 23 sites in 1998. The availability of suitable breeding sites suggests that numbers of cormorants breeding inland in England will continue to increase for the foreseeable future. Ringing studies and DNA analysis have proven that inland breeding cormorants in Great Britain are a mixture of Atlantic race *P. carbo carbo* and the continental race *P. c. sinensis*. DNA studies and field observations suggest that *sinensis* predominate, especially during initial colonisation. European *sinensis* populations show different migratory patterns to *carbo*, migrating over large distances to winter inland in Europe (especially France) and along the Mediterranean and North African coasts. Coastal breeding *carbo* populations however, tend to winter much closer to their breeding colonies on the Atlantic and North Sea coasts. This report describes the distribution and movements of inland breeding cormorants in England in relation to season, age, and colony of origin.

Of 1,645 cormorants ringed at four inland breeding colonies (1,336 at Abberton, 191 at Besthorpe Gravel Pits, Nottinghamshire, 81 at Rutland Water, Leicestershire, and 37 at Paxton Pits, Cambridgeshire), 53% of birds were resighted totalling some 4,078 sightings, mostly from southern and eastern England. Some 2-20% of birds were resighted abroad depending on the time of year. Most were resighted in winter, mainly from The Netherlands and France, but three birds were recovered from Spain and one from Tunisia. Only three birds from Besthorpe (2.8% of the total number of birds resighted) were resighted abroad compared with 61 birds from Abberton (8.6%). A much higher percentage (26%) of Abberton recoveries were overseas. This may more accurately reflect the true proportion of cormorants wintering overseas as resighting data may be biassed by a higher ring reading effort in England. Cormorants resighted overseas were predominantly young birds, with 90% of recoveries relating to birds of three years and younger. Cormorants were resighted at 269 different sites: 237 sites for Abberton birds, 48 for Besthorpe birds, 20 for Paxton birds and 11 for Rutland birds. However, individual birds were generally seen at only a few sites: 56% of birds were resighted at only one site, and 84% at one or two sites. Only 11 birds (all from Abberton) were seen at five or more sites with a maximum of seven sites used by one individual.

General linear modelling was used to investigate trends in latitude of resighting, distance from natal colony and proportion of resightings abroad. Besthorpe birds were resighted significantly further north than Abberton birds, even after taking into account the difference in latitude between the two colonies, and birds from both Abberton and Besthorpe were on average resighted to the north of their breeding colonies. First year birds were resighted further north than second year birds and adults. This combined with the greater tendency of young birds to be recovered abroad probably reflects the greater tendency for dispersal in immature birds. Cormorants of all ages were resighted further from their natal colonies during autumn and winter, on average some 90-120km away. Adults were found closer to their natal colonies than first or second year birds throughout the year, and first year birds were resighted further away than second year birds except during the post-fledging period. Juvenile cormorants dispersed rapidly from Abberton - within two months of fledging juveniles were resighted on average over 100km from the breeding colony. Mean resighting distance then remained at 100-150km until February from when birds moved back towards

Abberton. However, most birds apparently did not return to the colony in their first breeding season with a mean resighting distance of over 50km in May. Second year birds and adults did not show the rapid post-breeding dispersal characteristic of first years. Second year birds and adults returned to Abberton between January and March, although adults returned earlier than second year birds.

As DNA analysis, ringing, and observational studies have all suggested that English inland cormorant colonies hold significant numbers of birds of *sinensis* origin and that appreciable numbers of these birds winter abroad, the UK should be involved in any further development and implementation of the African-Eurasian Management Plan for *sinensis* being produced under the African-Eurasian Waterbird Agreement (AEWA). In keeping with the recommendation of the AEWA that action plans be produced for species causing conflict with human interests, the UK should now produce a national action plan for cormorants, including both coastal breeding and inland breeding populations. Building on the extensive, government-funded research programme on the impact of cormorants on fish stocks in Great Britain due to be completed in 1999, this action plan should determine appropriate management measures for cormorants in the UK. Although this study was not designed to investigate site fidelity, movement data suggested that cormorants breeding in inland colonies in England dispersed widely during the non-breeding season, but individual birds appeared to be site faithful. This suggests that limited winter control of cormorants in England is unlikely to have an appreciable impact on inland breeding colonies. However, to predict the effect of winter control more detailed studies of dispersal and site fidelity in individual birds of known age and sex both within and between winters would be required. This study highlighted the need for ongoing and substantial colour-ringing effort at inland cormorant colonies in England if the development of inland breeding is to be monitored adequately. Trends in movements of inland breeding cormorants can only be explained if: a) sufficient individuals at sufficient colonies are ringed annually and on an ongoing basis; and b) adequate data on factors explaining trends in movements are collected.

1. Introduction

Many European countries have, in the last few years, experienced notable increases in the numbers of inland breeding cormorants of the Continental race *Phalacrocorax carbo sinensis* (hereafter *sinensis*). For example, total breeding numbers in Poland, Germany, the Netherlands, Sweden and Denmark increased from 4,900 pairs in 1971 to 94,700 pairs by 1995 (Bregnballe 1996), a mean annual rate of increase of 13% per year. An additional 50,000 pairs now breed elsewhere in Europe giving a world population of *sinensis* in the region of 150,000 pairs (Russell *et al.* 1996). Historically, British cormorants have been mainly of the nominate North Atlantic race *P. carbo carbo* (hereafter *carbo*), which bred on the coast and usually remained in coastal waters in winter, but there is growing evidence that *sinensis* now comprises an increasing proportion of both the wintering and breeding population in Great Britain, especially at inland sites.

Between 1970 and 1985, cormorants shifted their wintering distribution to exploit inland waterbodies, with the proportion of birds recovered inland doubling from 20% to 40% (Wernham *et al.* 1997). Since first breeding inland in England in 1981, the number of inland breeding cormorants increased to 1,437 pairs by 1998[1], a mean annual rate of increase of 35%. Ringing studies and DNA analysis have suggested that inland breeding cormorants in Great Britain are a mixture of Atlantic *carbo* and Continental *sinensis* (Ekins 1996, Goostrey 1997, Goostrey *et al.* 1998) and recent observational and morphological studies have suggested that *sinensis* predominate, especially during initial colonisation (Newson *in prep.*).

European *sinensis* populations show different migratory patterns to *carbo*, migrating over large distances to winter inland in Europe (especially France) and along the Mediterranean and North African coasts (Van Eerden & Munstermann 1995). Coastal populations of *carbo* however, tend to winter much closer to their breeding colonies on the Atlantic and North Sea coasts (Coulson & Brazendale 1968, Wernham *et al.* 1997). Preliminary analysis of the movements of cormorants breeding at Abberton Reservoir, Essex, suggested that 25% of birds may winter abroad (Ekins 1996) implying that Abberton cormorants may show similar migratory habits to European populations of *sinensis*.

Although there have been a number of past studies on the movements of cormorants breeding at Abberton (Ekins 1990, 1994, 1996, 1997, Ekins & Hughes 1994), this is the first detailed analysis of these data and the first to include other inland colonies. This report aims to describe the distribution and movements of inland breeding cormorants in England in relation to season, age, and colony of origin, and thus to identify times and locations at which cormorants originating from these colonies may be sensitive to control.

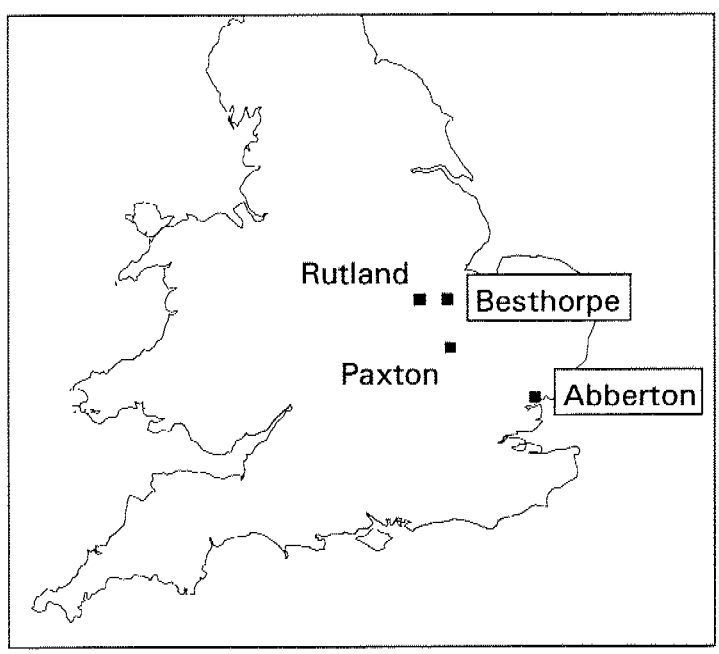
[1] Including a known underestimate of 30 pairs at Deeping St. James, Lincs, where access is restricted and which held 120 pairs in 1995.

2. Study sites and methods

2.1 Ringing studies

The study is based on resightings and recoveries (subsequently referred to as resightings) of 1,645 cormorants ringed as 4-5 week old pulli at four inland breeding colonies in England, the majority from Abberton Reservoir (51°49'N, 0°51'E) and Besthorpe Gravel Pits, Nottinghamshire (53°10'N, 0°45'W) (Figure 1, Table 1).

Figure 1. Geographic location of four cormorant inland breeding colonies in England included in the current analysis of movements and distribution.



Metal-ringing began at Abberton in 1989, colour-ringing the following year. In the first two years of colour-ringing at Abberton, 48 and 50 birds were colour-ringed. Subsequently, a sub-sample of 129-161 (mean 145 ± 4 (SE)) Abberton pulli have been colour-ringed. At the three other inland colonies (Besthorpe; Paxton Pits, Cambridgeshire (52°14'N, 0°15'W); and Rutland Water, Leicestershire (52°39'N, 0°41'W)), ringing began in 1995 with a total of 309 birds fitted with both metal and colour rings by 1998. Colour-ringing at Rutland, Besthorpe and Abberton is ongoing, but has been curtailed at Paxton Pits due to operational constraints.

Table 1. Number of cormorant pulli ringed at four inland colonies in England, 1989-1998. Figures in parentheses at Abberton are numbers of birds ringed with metal rings only.

Year	Abberton	Besthorpe	Paxton	Rutland	TOTAL
1989	101 (101)	-	-	-	101
1990	148 (100)	-	-	-	148
1991	70 (20)	-	-	-	70
1992	129	-	-	-	129
1993	145	-	-	-	145
1994	152	-	-	-	152
1995	148	15	22	44	229
1996	161	61	15	18	255
1997	149	84	-	-	233
1998	133	31	-	19	183
TOTAL	1336	191	37	81	1645

2.2 Geographical distribution of resightings

Records for which details were incomplete or uncertain were excluded, leaving a total of 3,121 resightings of 830 birds. These resightings were then mapped by colony, age class (first year, second year and adult (three years and older)), month of the year and month since ringing. These distribution maps are appended as Annexes 1-4 with individual maps included in the text to illustrate salient points.

2.3 Factors explaining movements and distribution

General linear modelling in GLIM (Crawley 1993) was used to investigate trends in latitude of resighting, distance from natal colony and proportion of resightings abroad. To reduce problems of pseudoreplication, only one replicate per bird was included for each month and site. Birds from Paxton Pits and Rutland Water were excluded due to small sample size. In order to normalise resighting data, 20 resightings of six birds at latitudes less than 48° (just south of Paris) were also excluded leaving a total of 3,101 resightings of 824 birds.

The main effects included in general linear models were:

1. month (continuous variable);

2. month^2 (continuous variable). As the relationship between month and latitude was curvilinear, a quadratic month term was included;

3. year (factor of nine);

4. colony (factor of two: Abberton and Besthorpe);

5. age class (factor of three: first year, second year, adult).

2.3.1 Latitude of resighting

As the data were normally distributed, a Normal error distribution and identity link were used (Crawley 1993). Model development proceeded by adding all main effects and all possible first, second and third order interactions to produce the full model. The minimal adequate model was then produced by removing non-significant interactions and main effects, beginning with the higher order interactions and removing the least significant first ($P>0.05$). Significance was assessed by removing terms from the full model and inspecting the changes in deviance with respect to the change in the degrees of freedom (Crawley 1993). Following production of the minimal adequate model, main effects and first order interactions were added individually to the model to check all were still non-significant. As the single third order interaction term was non-significant, the significance of second order interactions was assessed by removing and replacing them from the minimal adequate model; the significance of first order interactions was assessed by removing and replacing them from a model of main effects and significant first order interactions only; the significance of main effects from a model of significant main effects only.

2.3.2 Distance between ringing and resighting site

Log transformed distances proved to be normally distributed, so a normal error distribution and identity link were used (Crawley 1993). Model development proceeded by adding all main effects and all possible first, second and third order interactions to produce the full model. The minimal adequate model was then produced by removing non-significant interactions and main effects, beginning with the higher order interactions and removing the least significant first ($P>0.05$). Significance was assessed by removing terms from the full model and inspecting the changes in deviance with respect to the change in the degrees of freedom (Crawley 1993). As the single third order interaction term was non-significant, the significance of second order interactions was assessed by removing and replacing them from the minimal adequate model; the significance of first order interactions was assessed by removing and replacing them from a model of main effects and significant first order interactions only; the significance of main effects from a model of significant main effects only.

2.3.3 Proportion of birds resighted abroad

To investigate factors affecting the proportion of cormorants resighted abroad, a data matrix was constructed containing the total number of birds resighted and the total resighted abroad for each age class, month and year combination for the Abberton and Besthorpe colonies. A binomial error distribution and logit link were used with the number of birds sighted abroad per month as the response variable and the total number of birds resighted per month as the binomial denominator (Crawley 1993). Model development proceeded by adding all main effects and all possible first, second and third order interactions to produce the full model. The minimal adequate model was then produced by removing non-significant interactions and main effects, beginning with the higher order interactions and removing the least significant first ($P>0.05$). Significance was assessed by removing terms from the full model and inspecting the changes in deviance with respect to the change in the degrees of freedom (Crawley 1993). As all second and third order interaction terms were non-significant, the significance of first order interactions was assessed by removing and replacing them from the

minimal adequate model; the significance of main effects from a model of significant main effects only.

3. Results

3.1 Resighting rates

Of the 1,645 cormorants ringed at the four study sites, 53% were subsequently resighted, totalling some 4,078 resightings (Tables 2 & 3). Resighting rates for Abberton (54%) and Besthorpe were similar (56%), although fewer birds were seen from Paxton Pits and Rutland where fewer birds had been marked. The percentage of birds resighted from each age cohort (over the course of the whole study period) varied from 18 to 92% or 56-92% excluding the 1998 year cohort (for which only six months resighting data were available) and the 1989-1991 cohorts when 50 or fewer birds were colour-ringed (Table 2).

Table 2. Overall resighting rate of cormorants ringed at four inland colonies in England, 1989-1998, by year cohort. Figures in parentheses are total numbers of resightings. See Table 1 for numbers of birds ringed.

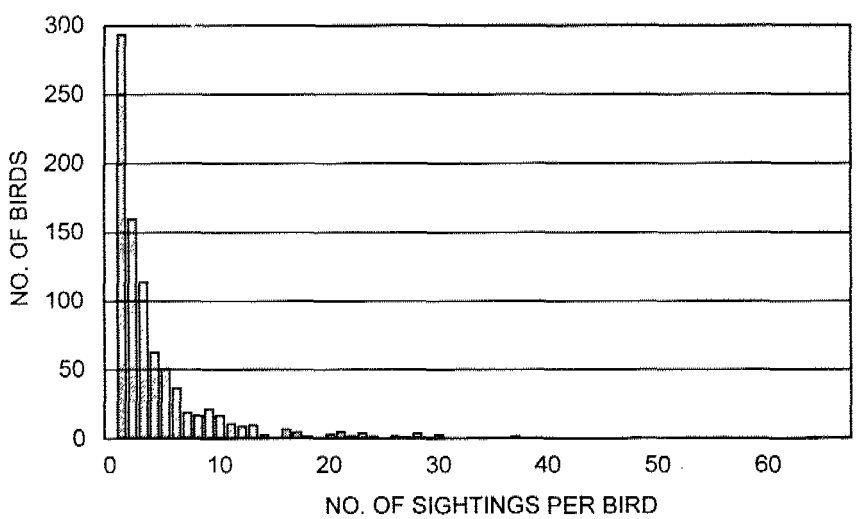
Year	Abberton		Besthorpe		Paxton		Rutland		TOTAL	
	No. birds resighted	%	No. birds resighted	%	No. birds resighted	%	No. birds resighted	%	No. birds resighted	%
1989	22 (32)	22	-	-	-	-	-	-	22 (32)	22
1990	35 (47)	24	-	-	-	-	-	-	35 (47)	24
1991	17 (25)	24	-	-	-		-	-	17 (25)	24
1992	86 (844)	67	-	-	-	-	-	-	86 (844)	67
1993	133 (731)	92	-	-	-	-	-	-	133 (731)	92
1994	114 (605)	75	-	-	-	-	-	-	114 (605)	75
1995	100 (561)	68	12 (97)	80	12 (40)	55	13 (78)	30	137 (776)	60
1996	104 (348)	65	49 (151)	80	4 (19)	27	11 (36)	61	168 (554)	66
1997	89 (256)	60	41 (136)	49	-	-	-	-	130 (392)	56
1998	24 (49)	18	5 (13)	16	-	-	8 (10)	42	37 (72)	20
Total	724 (3498)	54	107 (397)	56	16 (59)	43	32 (124)	40	879 (4078)	53

Table 3. Cumulative resighting rates of cormorants ringed at four inland colonies in England, 1989-1990. See Table 1 for numbers of birds ringed.

Year	Abberton		Besthorpe		Paxton		Rutland		TOTAL	
	No. birds resighted	% birds ringed	No. birds resighted	% birds ringed	No. birds resighted	% birds ringed	No. birds resighted	% birds ringed	No. birds resighted	% birds ringed
1990	9	4	-	-	-		-	-	9	4
1991	18	6	-	-	-		-	-	18	6
1992	71	16	-	-	-		-	-	71	16
1993	223	38	-	-	-	-	-	-	223	38
1994	343	46	-	-	-	-	-	-	343	46
1995	460	52	7	47	5	23	7	16	479	49
1996	581	55	54	71	12	32	22	36	669	54
1997	692	58	94	59	16	43	24	39	826	57
1998	724	54	107	56	16	43	32	40	879	53

Most cormorants were resighted only a small number of times after ringing (Figure 2), although one Abberton bird was resighted 67 times. Of the 20 birds seen 25 times or more since ringing, all but one were Abberton ringed birds, mostly resighted at Abberton and Hanningfield Reservoirs in Essex (51% of resightings). The other bird was ringed at Rutland Water and resighted mainly at Besthorpe.

Figure 2. Frequency distribution of the number of resightings per bird for cormorants ringed at four inland breeding colonies in England, 1989-1998.



Birds ringed at Abberton Reservoir were resighted more than birds from other colonies (Table 4), although differences between colonies in the numbers of resightings per bird were not significant (Mann-Whitney U-Tests, $P>0.05$).

Table 4. Number of resightings per bird for cormorants ringed as pulli at four inland colonies in England, 1989-1990.

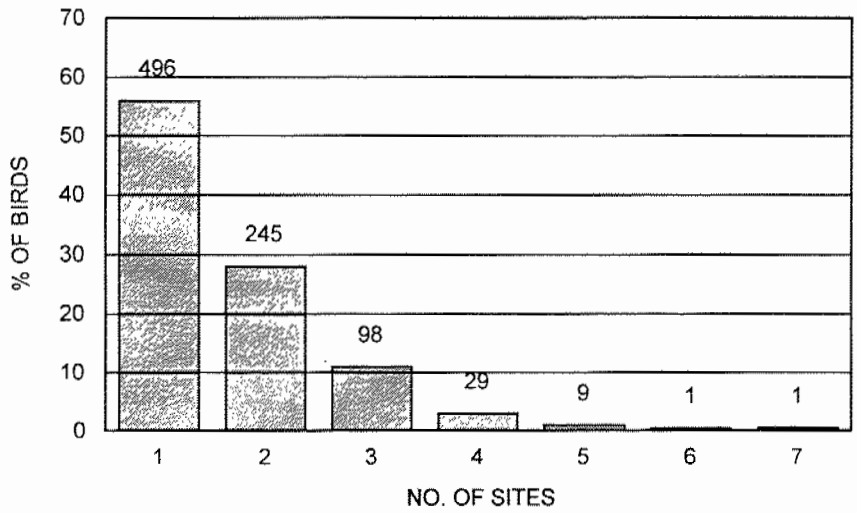
Colony	No. of birds	Mean	S.E.	Median	Min.	Max.
Abberton	724	4.83	0.27	2	1	67
Besthorpe	107	3.71	0.37	2	1	21
Paxton	16	3.69	0.66	3	1	10
Rutland	32	3.88	0.94	2	1	29
Total	879	4.64	0.23	2	1	67

Ringed cormorants were resighted at 269 different sites; 237 sites for Abberton birds, 48 for Besthorpe birds, 20 for Paxton birds and 11 for Rutland birds. However, individual birds were generally seen at only a few sites (Table 5, Figure 3): 56% of birds were resighted at only one site, and 84% at one or two sites. Only 11 birds (all from Abberton) were seen at five or more sites with a maximum of seven sites used by one individual.

Table 5. Number of sites at which cormorants ringed as pulli at four inland colonies in England, 1989-1990 were resighted.

Colony	No. of birds	Mean	S.E.	Median	Min.	Max.
Abberton	724	1.69	0.03	1	1	7
Besthorpe	107	1.48	0.07	1	1	4
Paxton	16	1.81	0.23	2	1	4
Rutland	32	1.28	0.09	1	1	3
Total	879	1.65	0.03	1	1	7

Figure 3. Frequency distribution of the number of sites at which cormorants ringed as pulli at four inland colonies in England, 1989-1990 were resighted. Data labels are number of birds resighted.



Most birds were resighted at sites with breeding colonies and/or roosts (Table 6). This reflects both the cormorant's fidelity to breeding and roosting sites and the fact that most resighting effort is conducted at such sites. However, no measure of resighting effort could be included in current analyses. A large proportion of resightings of cormorants were made at their natal colonies: 43.9% (1,537/3,498) for Abberton ringed birds, 54.4% (216/397) for Besthorpe ringed birds, 66.1% (82/124) for Rutland ringed birds, and 16.9% (10/59) for Paxton ringed birds.

Table 6. Sites with resightings of ≥10 cormorants ringed as pulli at four inland colonies in England, between 1989 and 1998. Sites with breeding records in bold, breeding colonies in upper case, and night roosts in italics.

Site	County	No. of Sightings	No. of Birds
ABBERTON RESERVOIR	Essex	1543	574
Hanningfield Reservoir	Essex	527	97
BESTHORPE GRAVEL PITS	Notts	288	86
RUTLAND WATER	Leics	166	50
Seal Sands	Cleveland	51	24
PAXTON PITS	Cambs	41	23
RYE HARBOUR	Sussex	87	20
Snettisham Pits	Norfolk	72	20
Trimley Marshes	Essex	38	16
Elmley RSPB Reserve	Kent	19	15
Holkham	Norfolk	34	15

Site	County	No. of Sightings	No. of Birds
Alton Water	Suffolk	69	13
Cley NNT Reserve	Norfolk	28	13
Bough Beech Reservoir	Kent	25	12
Loompit Lake	Essex	32	12
Top Hill Low NR	Humberside	47	12
Becton Sewage Farm	Essex	38	10
Coleman's Reservoir	Essex	23	10

First year birds were recovered and resighted most often, with numbers declining thereafter (Figures 4 & 5). The oldest bird resighted was an eight year old Abberton bird ringed in 1991 and resighted in the Netherlands.

Figure 4. Age specific resighting rate for cormorants ringed at four inland breeding colonies in England, 1989-1998.

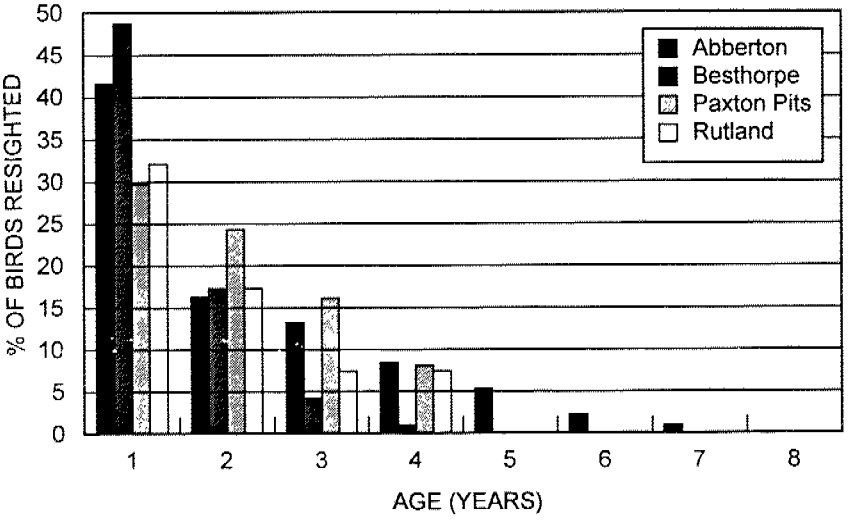


Figure 5. Age specific recovery rate for cormorants ringed at four inland breeding colonies in England, 1989-1998.

3.2 Resighting distribution

Cormorants from inland breeding colonies in England were resighted mainly within England and mostly close to their natal colony (Figure 6). However, resighting information was sparse for birds from Paxton Pits, Rutland Water and to some extent Besthorpe, where fewer birds had been ringed. Abberton birds were found mainly in south-east England, around the coast of East Anglia with some birds moving to the near continent and small numbers further south to Spain and Tunisia (see Section 3.2.3). Besthorpe birds had a more northerly distribution than Abberton birds, reflecting not only the more northerly location of the breeding colony, but a real tendency to remain further north (see Section 3.2.2).

Resightings of first and second year birds are much more widespread than those of adults (Figure 7). Although this may be partly due to the larger number of resightings of young birds, more detailed analysis suggests that younger birds do indeed disperse further than adults, especially with regard to dispersal abroad (see Sections 3.2.2 & 3.2.3).

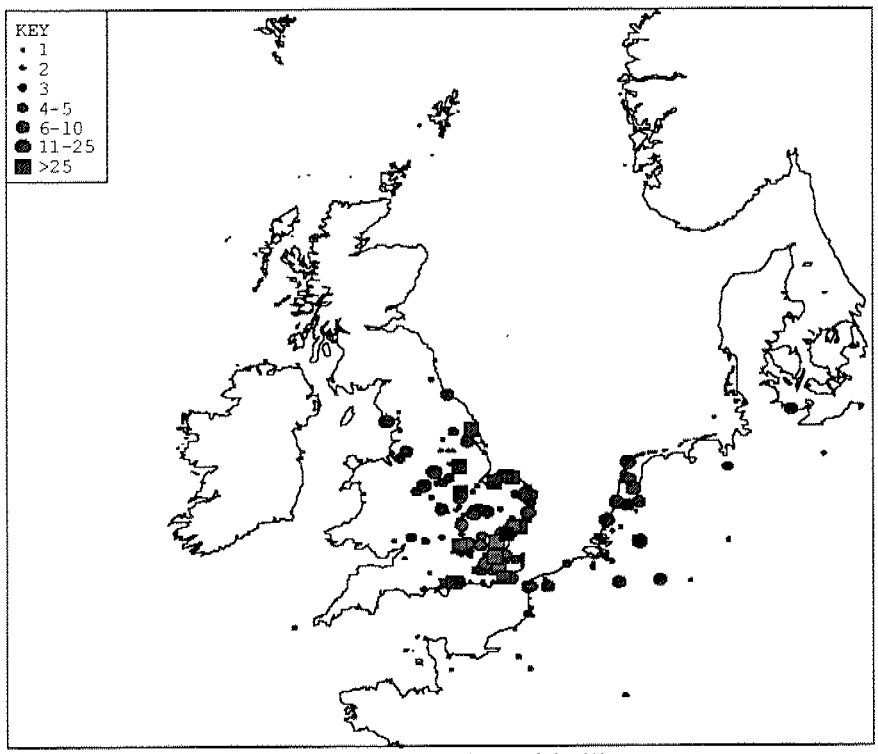
Cormorants breeding at inland colonies in England tend to be more concentrated during the breeding season and most dispersed immediately post-breeding. Thus from January (when adults begin to return to their breeding colonies) through to June (when the majority of young begin to fledge), resightings are less extensive (Figure 8, Annex 1). Between July and September resightings are more widely distributed then less so in November and December when the majority of birds have reached their wintering sites.

Examination of monthly resighting distributions of the three different age classes of cormorants suggests that although cormorants of all ages tend to be more concentrated during the breeding season, adults are much less dispersed during the non-breeding season than first year birds (Figure 9, Annexes 2-4)).

Post-fledging dispersal can be illustrated by considering cormorants ringed at Abberton in relation to month from ringing date. The first birds to fledge may leave the colony almost immediately with sightings away from Abberton within one month of fledging (Figure 10, Annex 5). Juvenile birds then rapidly disperse within their first two months (see Section 3.2.2), mostly within southern and eastern England, but also to the continent. Although some birds return to Abberton during their first breeding season (at about 12 months of age), many remain dispersed elsewhere.

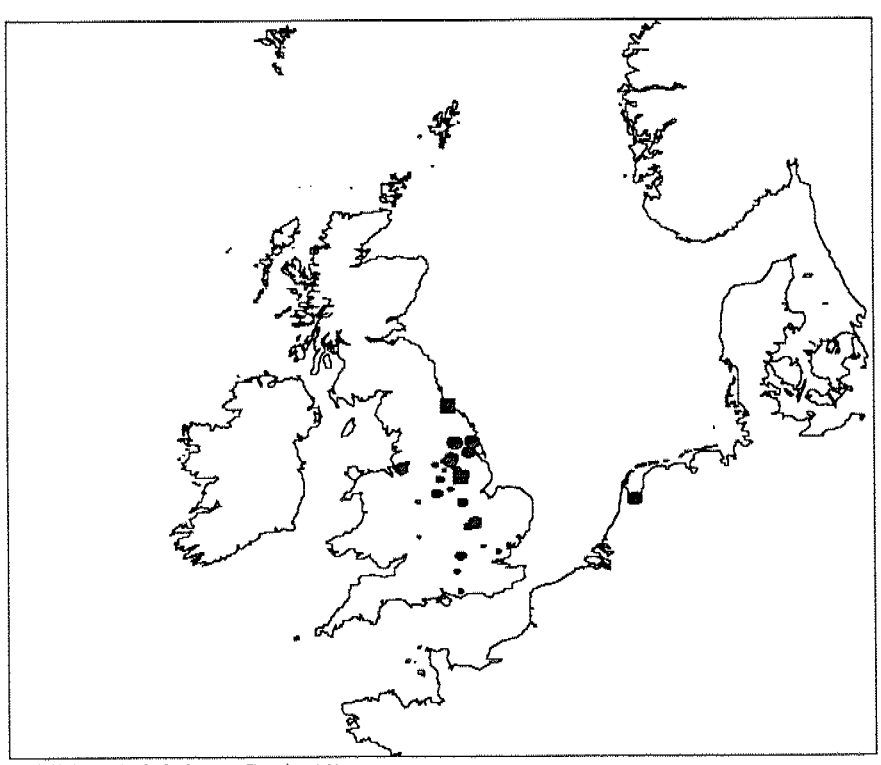
Figure 6. Resighting distribution of cormorants ringed as pulli at four inland breeding sites in England. Key in (a) applies to all maps. Study sites marked in black.

(a) Abberton Reservoir (N = 3498 resightings of 724 birds).



Additional sightings: France (14), Spain (3), Tunisia (1).

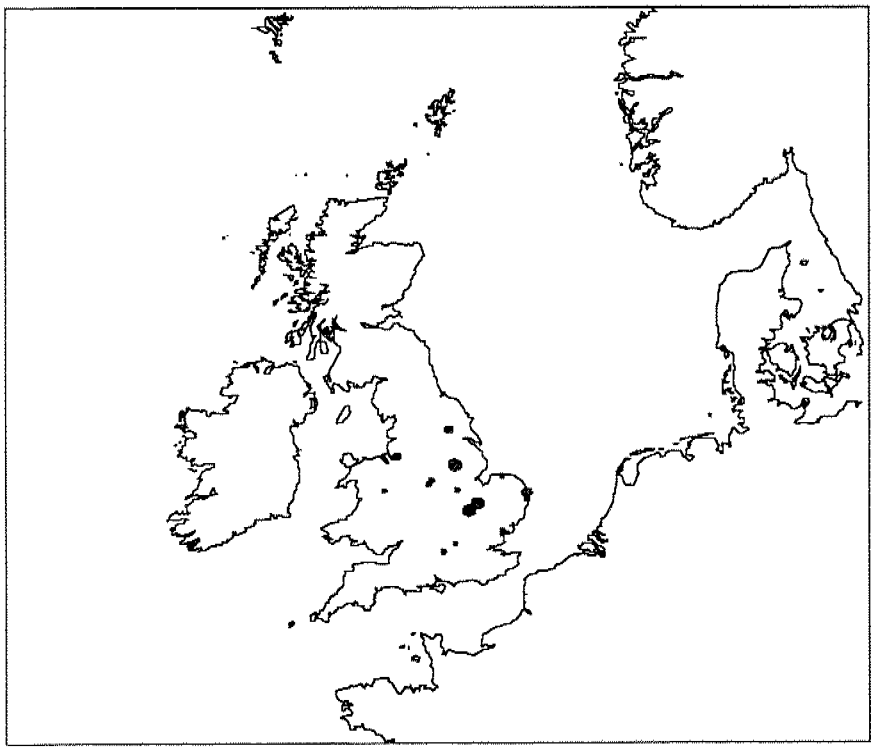
(b) Besthorpe Gravel Pits (N = 397 resightings of 107 birds).



Additional sightings: Spain (4)

Figure 6 (cont.). Resighting distribution of cormorants ringed as pulli at four inland breeding sites in England. Key in (a) applies to all maps.

(c) Paxton Pits (N = 59 sightings of 16 birds).



(d) Rutland Water (N = 124 sightings of 32 birds).

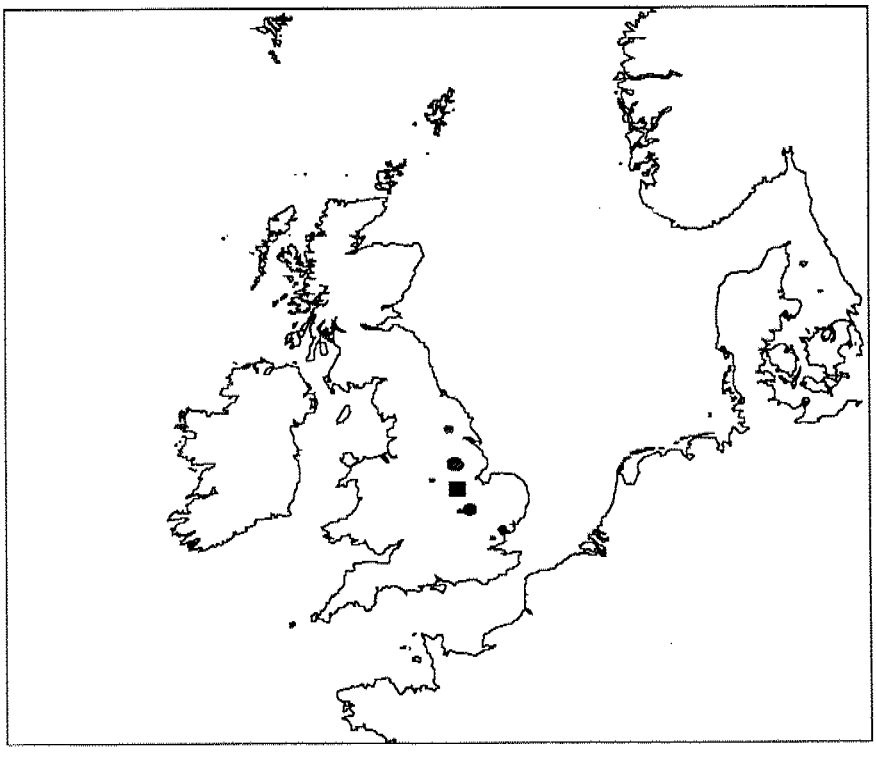
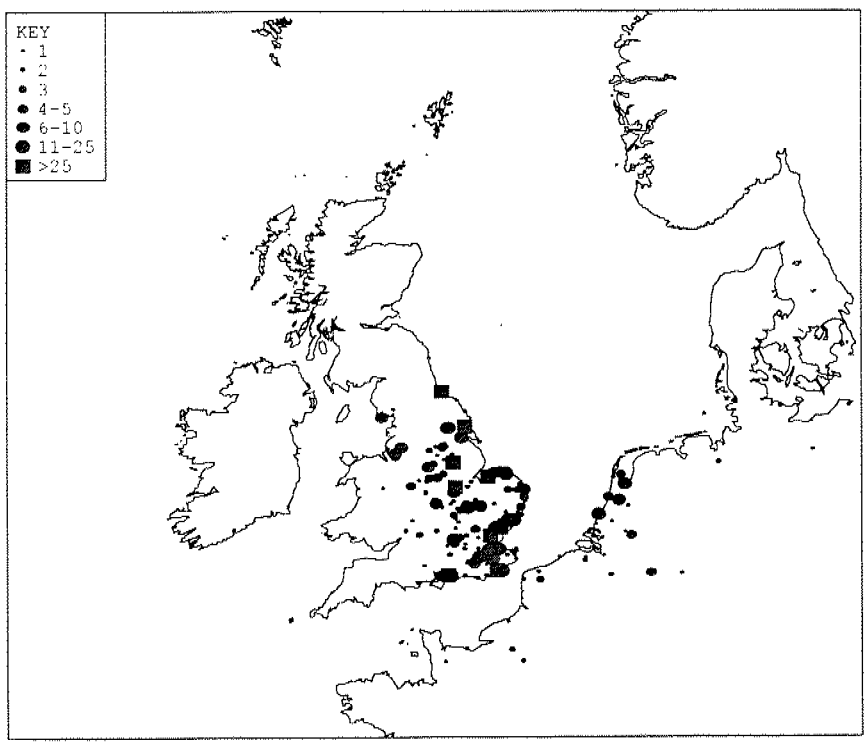


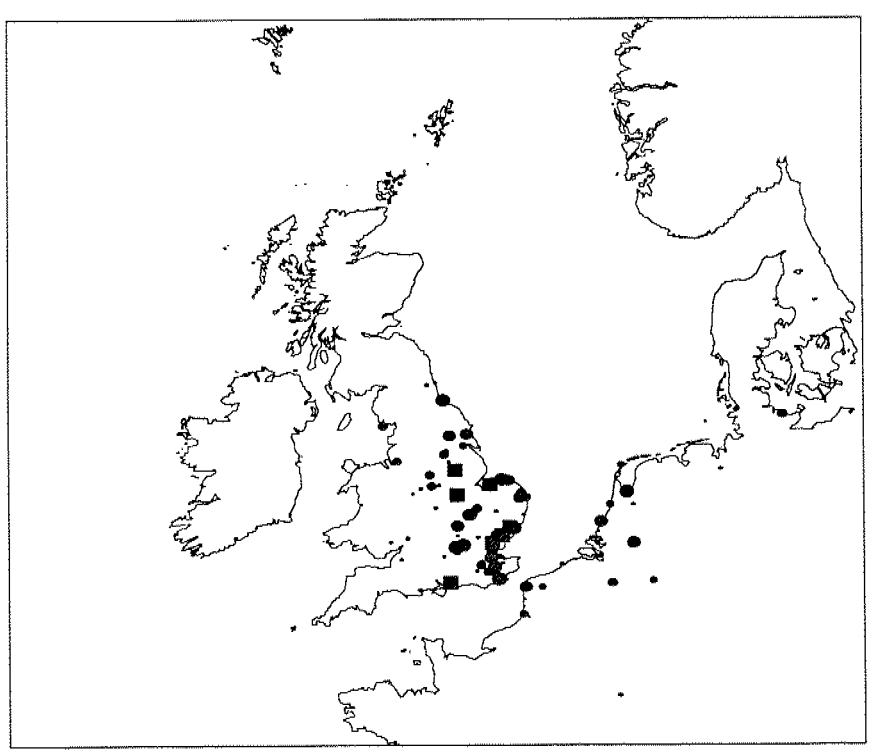
Figure 7. Resighting distribution of cormorants ringed as pulli at four inland breeding sites in England in relation to age at resighting. Key in (a) applies to all maps.

(a) First years (N = 1970 resightings of 720 birds).



Additional sightings: France (12), Spain (1),Tunisia (1).

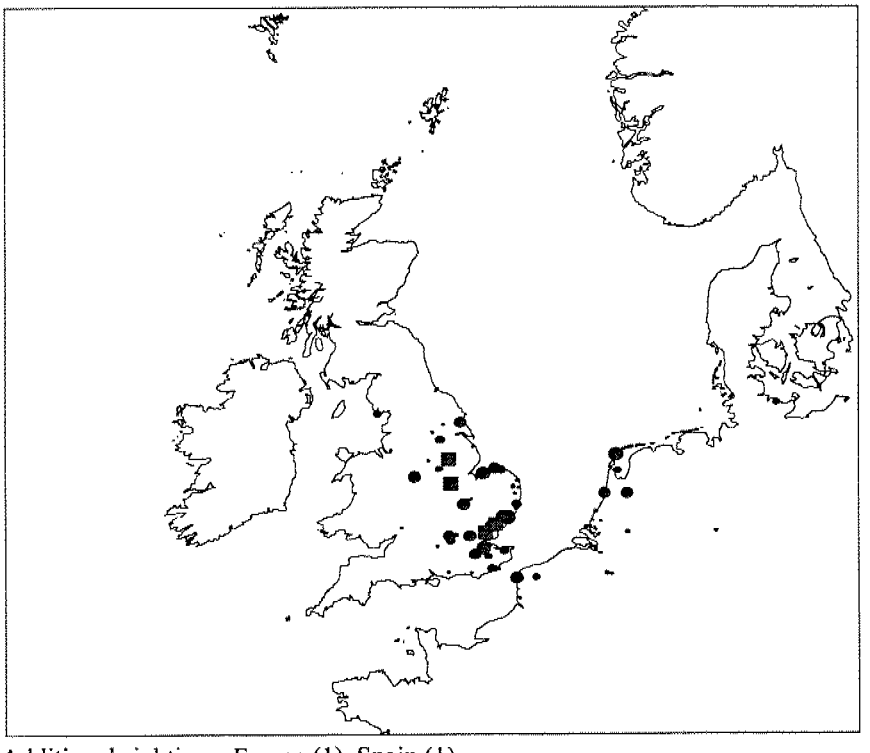
(b) Second years (N = 963 resightings of 281 birds).



Additional sightings: France (1), Spain (5).

Figure 7 (cont.). Resighting distribution of cormorants ringed as pulli at four inland breeding sites in England in relation to age at resighting. Key in (a) applies to all maps.

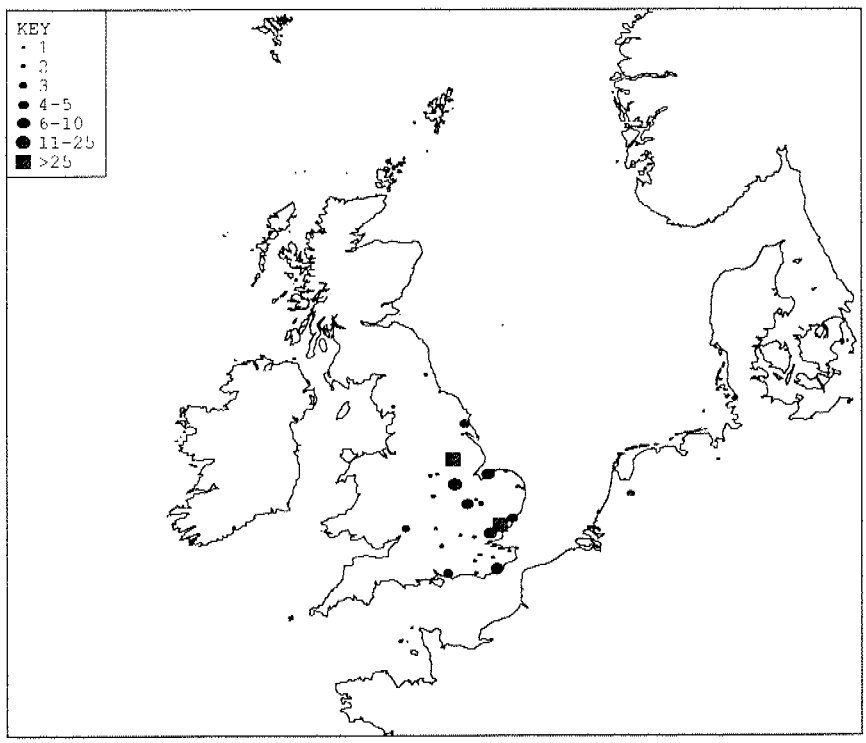
(c) Adults (N = 1145 resightings of 286 birds).



Additional sightings: France (1), Spain (1).

Figure 8. Resighting distribution of cormorants ringed as pulli at four inland breeding sites in England during the breeding (May) and post-breeding (September) periods.

Breeding



Post-breeding

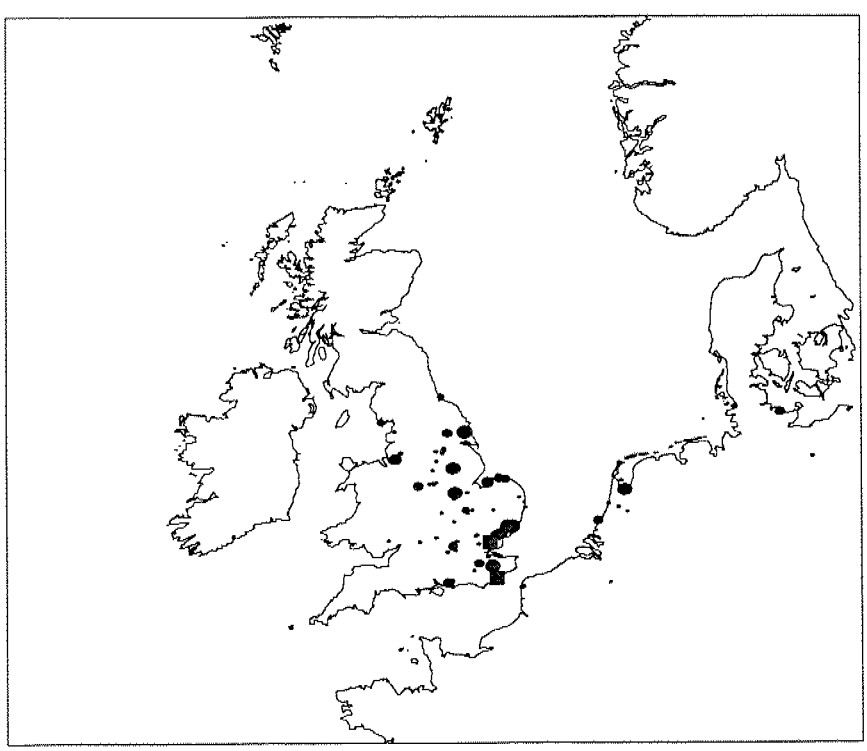
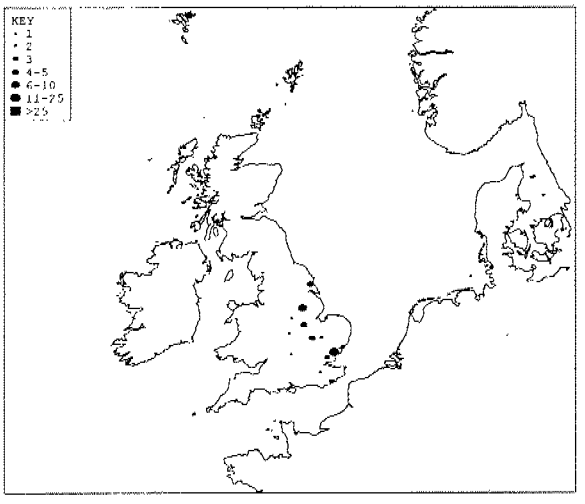
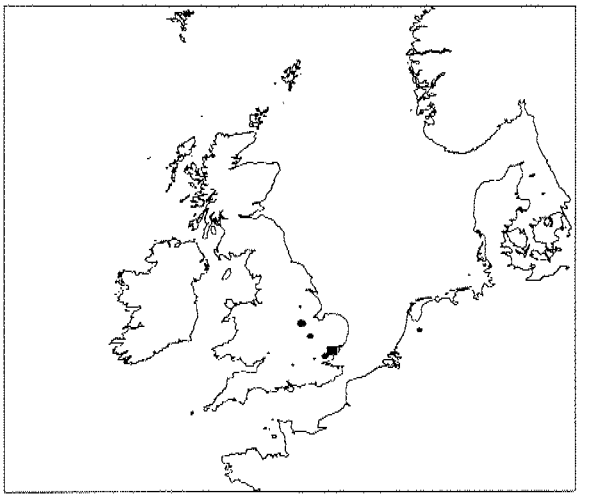


Figure 9. Breeding, post-breeding and wintering resighting distribution of cormorants ringed as pulli at four inland breeding sites in England and resighted as first years or adults.

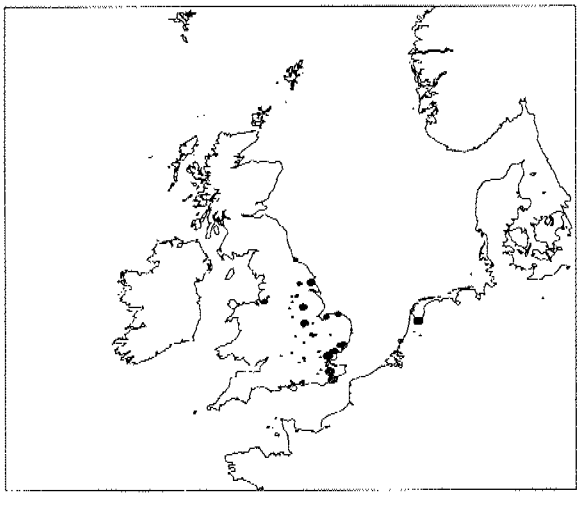
First years, Breeding



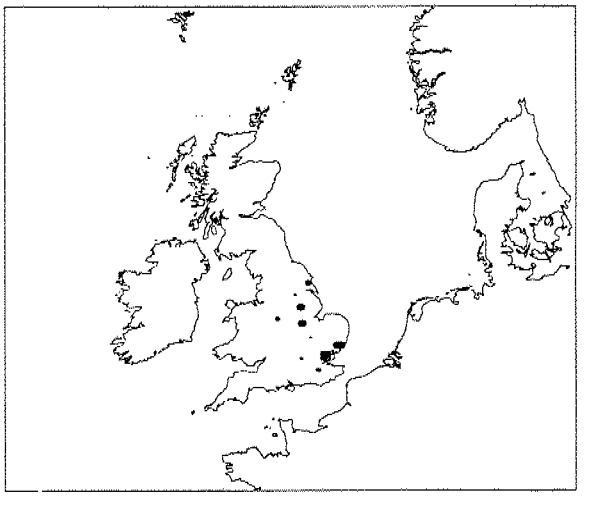
Adults, Breeding



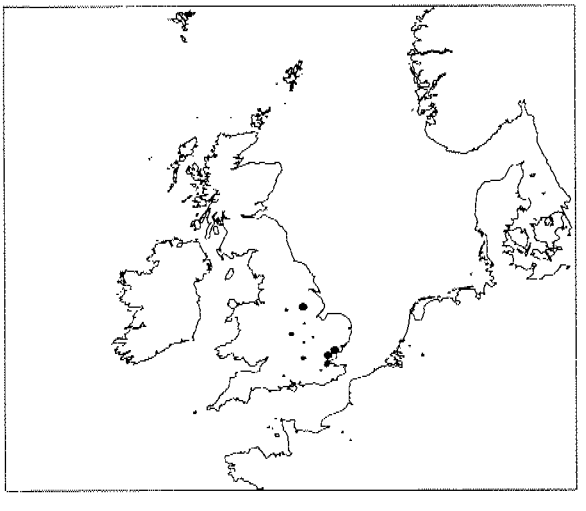
First years, Post-breeding



Adults, Post-breeding



First years, Wintering



Adults, Wintering

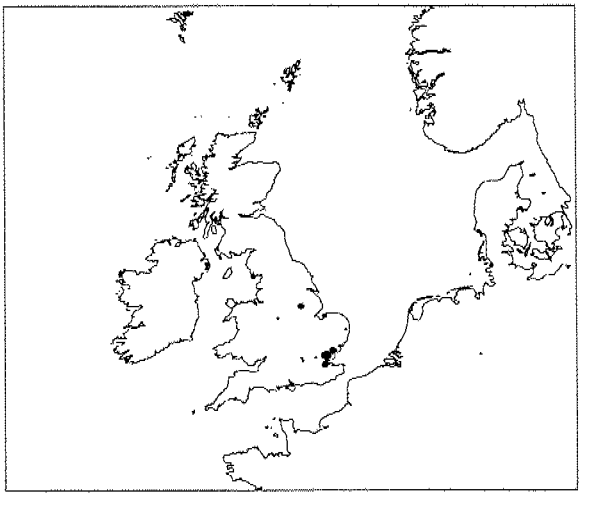
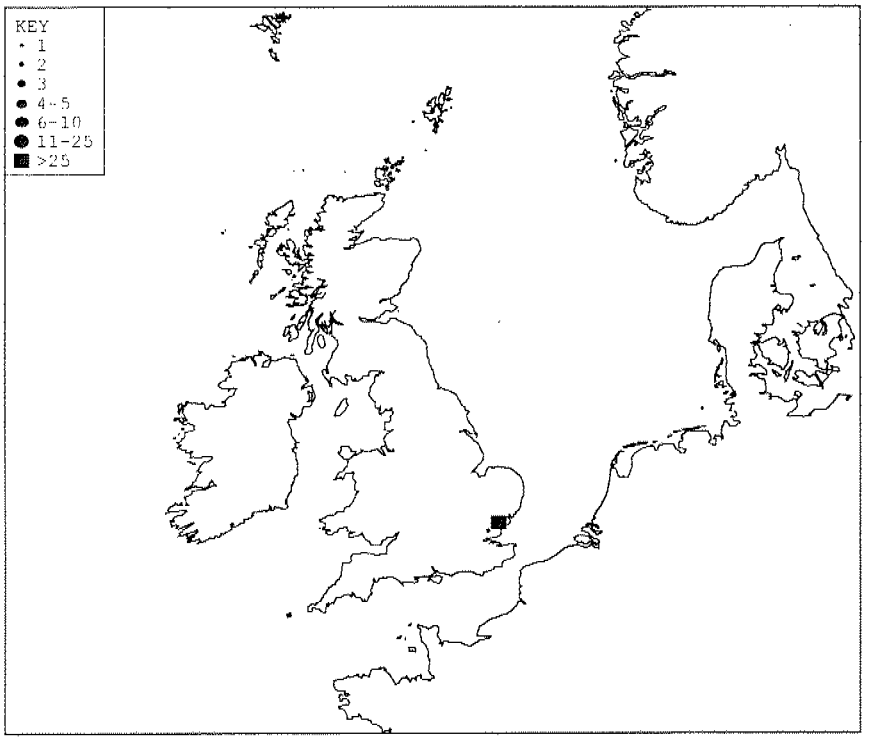


Figure 10. Resighting distribution of cormorants ringed as pulli at Abberton Reservoir, Essex, in relation to month from ringing date (≡ age). Key in (a) applies to all maps.

(a) <1 Month Old



(b) 1-2 Months Old

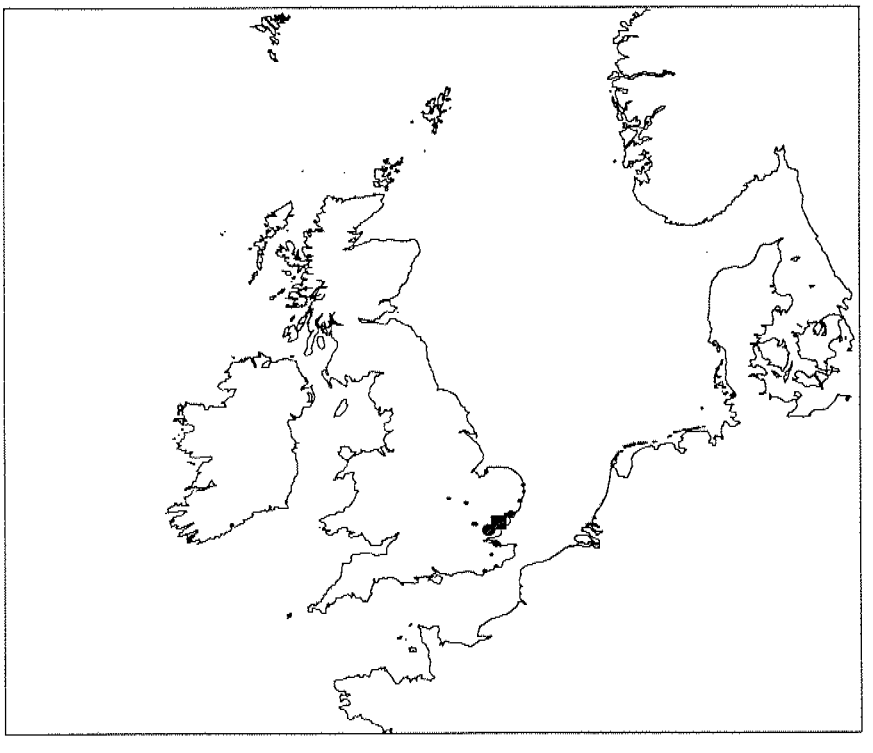
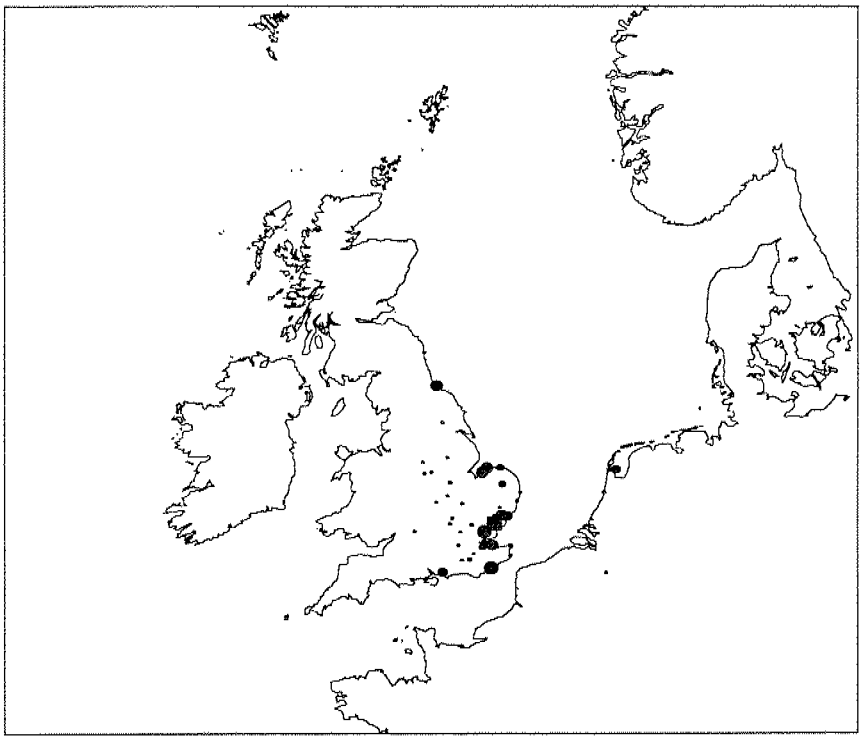


Figure 10 (cont.). Resighting distribution of cormorants ringed as pulli at Abberton Reservoir, Essex, in relation to month from ringing date (≡ age). Key in (a) applies to all maps.

(c) 2-3 Months Old



(d) 3-4 Months Old