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Cormorants along the River Wensum: an Analysis of Habitat Associations

Authors

M.J.S. Armitage, G.E. Austin & M.M. Rehfisch

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The National Centre for Ornithology, The Nunnery, Thetford, Norfolk IP24 2PU
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CONTENTS

Page No.

List of Tables ... 3
List of Figures ... 5
List of Appendices ... 5

EXECUTIVE SUMMARY ... 7

1. INTRODUCTION ... 9

2. METHODS ... 11

2.1 Waterways Breeding Bird Survey (WBBS) ... 11
2.1.1 Count Methodology ... 11
2.1.2 Analysis ... 11
2.2 Intensive Cormorant Surveys on the River Wensum ... 11
2.2.1 Count Methodology ... 11
2.2.2 Analysis ... 13

3. RESULTS ... 15

3.1 Waterways Breeding Bird Survey ... 15
3.2 Intensive Cormorant Surveys on the River Wensum ... 17
3.2.1 Cormorant numbers on still waters versus rivers ... 19
3.2.2 Cormorant numbers according to riverine habitat ... 19
3.2.3 Cormorant numbers according to still water habitat ... 19

4. DISCUSSION ... 21

5. RECOMMENDATIONS FOR FURTHER WORK ... 23

Acknowledgements ... 24
References ... 25
Figures ... 27
Appendices ... 31

List of Tables

Page No.

Table 2.2.1.1 Visit dates by site for River Wensum Cormorant Survey...12

Table 3.1.1. Occurrence of cormorants on canals and rivers as recorded by WBBS, 1998 to 2000 15

Table 3.1.2. Occurrence of cormorants on waterways with and without dredging as recorded by WBBS, 1998 to 2000 15

Table 3.1.3. Occurrence of cormorants on waterways with and without bank clearance as recorded by WBBS, 1998 to 2000 16

Table 3.1.4. Occurrence of cormorants on waterways with dystrophic (defined as being black water), oligotrophic (clear) and eutrophic (green) water as recorded by WBBS, 1998 to 2000 16

Table 3.1.5. Occurrence of cormorants on waterways with and without disturbance as recorded by WBBS, 1998 to 2000 17

Table 3.1.6 Occurrence of cormorants on fast flowing and slow or medium flowing waterways as recorded by WBBS, 1998 to 2000...17

Table 3.2.1. Habitat descriptors of pools 18

Table 3.2.2. Habitat descriptors of river stretches 18

List of Figures

Page No.

Figure 2.2.1.1 Cormorant survey sites in the upper Wensum Valley..27

Figure 2.2.1.2 Cormorant survey sites in the middle Wensum Valley..28

Figure 2.2.1.3 Cormorant survey sites in the lower Wensum Valley..29

List of Appendices

Page No.

Appendix 1 Habitat recording codes used for WBBS survey 31

Appendix 2 Numbers of cormorants recorded in each 90 minute period during the first site surveys..33

Appendix 3 Numbers of cormorants recorded in each 90 minute period during the second site surveys..35

Appendix 4 Numbers of cormorants recorded in each 90 minute period during the third site surveys..37

Appendix 5 Numbers of cormorants recorded in each 90 minute period during the final site surveys..39

EXECUTIVE SUMMARY

1. The River Wensum, an enriched, spring-fed, calcareous, lowland river, is a Site of Special Scientific Interest in Norfolk, totalling 71 km in length from its source near Fakenham, to Costessy near Norwich.

2. The Wensum has been extensively modified over thousands of years, impacting on the hydrology and ecology of the river. There is some evidence that the fish populations may have declined in the last 50 years and there are plans for the rehabilitation of parts of the river, in part to improve its quality as a self-sustaining viable fishery.

3. Cormorants are piscivorous birds that may influence fish population dynamics in the Wensum Valley. This study was put in place to determine the broad-scale habitat features that are favoured or avoided by foraging cormorants.

4. Analysis of Waterways Breeding Bird Survey data from 1998, 1999 and 2000 did not identify any habitat features that attracted or deterred cormorants from river stretches.

5. Analysis of intensive survey data collected along the River Wensum in winter 2000-2001 showed that significantly more cormorants used still water bodies than the river. Of the still water sites, significantly more cormorants were found at sites actively stocked with fish than those that were not and also at sites with one or more islands in the water body. The birds are probably attracted by higher densities of fish and a safe place to roost/loaf when not foraging. Significantly fewer cormorants were recorded at sites with anglers present. On the river, significantly more cormorants were recorded foraging on stretches with poor channel vegetation than on stretches with higher water-weed growth. This may be due to the fish being more visible to cormorants, or easier to catch in areas without much channel vegetation.

6. The number of cormorants recorded on the river was very low (nine sightings out of 312 samples) and other habitat features, including river width, flow-rate, fish biomass and bank-side vegetation were not significant in explaining the distribution of cormorants.

7. The River Wensum does not appear to be seriously threatened by cormorant depredation, particularly during the summer, when very few birds are present in the valley. However, it is possible that the modest predation pressure observed during the winter could have a disproportionate effect on the declining, fragmented roach and dace populations. Cormorants are more numerous at the still water bodies associated with the river, where they may be damaging fish stocks. The national cormorant population has stabilised in recent years, following increases throughout the 1970s and 1980s, although numbers continue to increase inland. If numbers were to increase considerably along the River Wensum, it is possible that more use would be made of the river by foraging cormorants.

8. Intensive monitoring of the river in areas with adjacent stretches free of weeds and with weeds could help identify the fine scale factors that help determine cormorant site preferences. The use of fake vegetation could be trialled to assess whether it is a useful deterrent to foraging cormorants. Cormorants are probably a particular problem on stocked still waters. Monitoring of these sites just before and after stocking could help identify when the sites need most protection.

1. INTRODUCTION

The River Wensum in Norfolk comprises 71 km of river, from its source near Fakenham, to Costessey near Norwich. The Wensum is one of the best examples of an enriched, calcareous, lowland river and was designated as a Site of Special Scientific Interest (SSSI) in 1993, supporting over 100 species of plants, most notably pondweeds (*Potamogeton* spp.), and a rich invertebrate fauna. The SSSI includes two of the tributary rivers, the Tat and the Langor Drain, as well as 20 parcels of land with an area of 393 hectares (Perrow & Punchard 1998).

The river has been subject to many modifications for several thousand years, including forest clearance, widening, deepening, straightening, embanking and watermill installation. These alterations to the surrounding environment and the flow of the river have had a substantial effect on the ecology and hydrology of the river and a major impact on the fish community. There is anecdotal and scientific evidence that since the Second World War, populations of native species, including roach (*Rutilus rutilus*), dace (*Leuciscus leuciscus*), perch (*Perca fluviatilis*) and trout (*Salmo trutta*), may have declined. These declines are largely thought to be due to poor recruitment rates, possibly resulting from increases in water abstraction, lower water quality or reduction in habitat diversity.

The Wensum has long been regarded as a fishery, with a variety of coarse species present. In the 1960s and 1970s, the river was regarded as one of the finest roach fisheries in the country, and there are concerns from angling interests over the perceived declines in its cyprinid fish species. However, the Wensum still supports a diverse fish fauna and twenty-three species are known from the river. These include bullhead (*Cottus gobio*) and brook lamprey (*Lampetra planeri*), listed under Annex II of the Habitats Directive. Currently the fish fauna is dominated by chub and eels (Perrow & Punchard 1998). The perceived decline in the fishery has not yet been proven, but should this be established, the factors responsible would need to be determined in order that recommendations could be made for the rehabilitation of the river as a self-sustaining viable fishery.

One feature that may have a negative impact on fish populations is predation. Many cormorants (*Phalacrocorax carbo*) typically leave coastal areas in September to reach maximum numbers in inland habitats, such as reservoirs and gravel pits, between December and February. Cormorants use the River Wensum and its associated water bodies for foraging, and this may influence fish population dynamics in the river. The population of cormorants wintering in Britain has increased steeply over the last 25 years and the establishment of new inland colonies may have led to increased use of inland waters throughout the year (Rehfisch *et al.* 1999). They are perceived to have a deleterious effect on fisheries, through predation, damage to fish caught but not killed, disease transmission, and effects on fish behaviour influencing their growth and catchability (Davies *et al.* 1995; Russell *et al.* 1996; Carss & Marquiss 1997). However, reports on the effect of cormorants on fisheries are often anecdotal and contradictory, and fierce debate has occurred over whether these birds actually decrease fish stocks (Draulans 1988; Suter 1991, 1995; Russell *et al.* 1996).

Depredation of fish stocks can be locally severe. For example, stock losses of rainbow trout (*Oncorhynchus mykiss*) increased from 15% to 98%, due to cormorant predation, when protective netting was removed from experimental ponds in Denmark (Dieperink 1995). At ponds in Hertfordshire, a 60% difference in mortality between netted and open ponds was assumed to be due to cormorants (McKay *et al.* 1999). However, outside small, enclosed systems such as these, there is an absence of irrefutable evidence that cormorants cause serious damage to fisheries. Case studies on the rivers Ribble and Trent (Feltham *et al.* 1999) suggested that 14% - 30% and 5% - 55% respectively of the standing crop of fish were removed by cormorants in winter. However, on the Ribble, it was not thought that cormorants were responsible for driving the fish population changes, but rather that they were reacting to it. On the Trent, parts of the river showed positive correlation between depredation and fishery performance, but catches were also related to water quality and temperature.

The primary objective of this study was to identify habitat features of the River Wensum that are favoured or avoided by foraging cormorants, and to suggest easily applicable management routines that should make the river less attractive to cormorants. Emphasis was placed on trying to detect factors that can be managed with relative ease, that do not impact on the natural value of the area and that do not have a negative impact on the recreational use of the river.

The secondary objective was to identify broad-scale habitat features that might be favoured or avoided by foraging cormorants from the UK sites counted as part of the Waterways Breeding Bird Survey (WBBS).

2. METHODS

2.1 Waterways Breeding Bird Survey (WBBS)

2.1.1 Count Methodology

The WBBS is a national survey of breeding birds along rivers and canals. The survey has been carried out annually since 1998. The WBBS is based on bird counts obtained from 500-metre sections along stretches of waterway. All birds seen are recorded and observations are classified according to distance category (< 25 metres, 25 – 100 metres, > 100 metres, flying over) from the waterway. Where access allows, waterway stretches are comprised of 10 adjoining 500-metre sections although there is no lower limit to the number of adjoining sections that must be included. Observers make three visits to their waterway stretches, the first to record habitat types, and the second and third to record birds. Habitat recording adheres to a standardised system used widely across various BTO surveys (Appendix 1). The second and third visits take place between 1st April and 30th June, starting 06:00 and 07:00 BST and with at least a four week gap between them.

2.1.2 Analysis

Cormorant and habitat associations were investigated using chi-squared contingency tests (Everitt 1977). For WBBS, only the recording of habitats associated with water bodies is compulsory while recording of other habitats is at the discretion of the surveyor as the latter are less important for a waterways based survey than for other BTO surveys. Analysis was therefore restricted to habitats recorded for water bodies (Appendix 1, Level G, water bodies (fresh water)) because other habitats were each recorded too infrequently to support the necessary statistical tests. Habitat sub-categories (levels 2, 3 and 4) were combined where necessary to allow statistical tests.

2.2 Intensive Cormorant Surveys on the River Wensum

2.2.1 Count Methodology

Twenty-six individual sites along the River Wensum were selected for survey, comprising 14 river stretches and 12 still water sites (Figures 2.2.1.1-2.2.1.3). These were determined in consultation with the Environment Agency (EA) and the Norfolk Anglers Conservation Association (NACA) and ensured that coverage of a suitable range of different habitat types was obtained. In order to collect data efficiently, sites close to each other were grouped to enable several sites to be surveyed at fixed intervals throughout the day. The groups of sites and dates of surveys are shown in Table 2.2.1.1.

All selected sites were surveyed for the equivalent of one day, between 05.00 and 20.00 BST during late May/early June with the exception of the Sparham/Lyng sites, which were surveyed on two occasions. No cormorants were observed feeding at any of the sites during these visits, therefore, after consultation with the EA and NACA, it was decided to carry out the surveys during October and November, when over-wintering migration of fish takes place and there is an increase in the number of cormorants foraging inland (Rehfisch *et al.* 1999). However, river flooding during these months further delayed the fieldwork, which was then carried out between December and February (Table 2.2.1.1). The two sites at Lenwade were not surveyed during this period.

Site groups	Summer 2000 05.00 – 20.00	Winter 2000/01 07.30 – 16.30
Pensthorpe & Great Ryburgh	19 May	29 December
UP1		10 January
UP2		04 February
OR1		08 February
OR2		
Sennowe Park	22 May	20 December
UP3		19 January
UP3A		31 January
CR1		15 February
CR2		
Billingford	24 May	18 December
SP1	25 May	14 January
SP1A		06 February
OR6		19 February
OR7		
Sparham & Lyng	23 May	11 January
SP2	25 May	12 January
OR10		21 January
OR11		02 February
UP6		
UP6A		
CR3		
OR12		
Lenwade	31 May	No surveys
SP3	01 June	
CR4		
Ringland & Taverham	26 May	15 December
OR13		26 January
SP4		07 February
CR7		13 February
SP5		
CR8		

Table 2.2.1.1 Visit dates by site for River Wensum Cormorant Survey (see Figures 2.2.1.1-2.2.1.3).

River stretches were surveyed by walking or driving alongside the river, recording the number of feeding cormorants observed. Still water bodies were surveyed by scanning the surface with binoculars and recording the number of feeding cormorants observed, ensuring none were overlooked while they were foraging underwater. Each group of sites was surveyed every 90 minutes between 07.30 and 16.30 GMT during the winter visits. In addition to these data, notes were made on the number of cormorants roosting nearby, and on the presence of any activities potentially causing disturbance.

Habitat recording was based on the WBBS habitat recording methodology. In addition river flow rate (categorised as slow, average or gliding) was recorded and data on fish stocks collated (EA 1997a,b,c).

2.2.2 Analysis

Cormorant and habitat associations were investigated using generalised linear models (McCullagh & Nelder 1989). This statistical method assesses the ability of measurable factors (in this case, habitat features) to explain the variation between observations (in this case, numbers of cormorants). The strength of any associations detected are assessed for statistical significance. While a statistically significant relationship between a factor and the observation does not necessarily imply a causal relationship (that the factor is responsible for the observation), we would expect that a strong causal relationship would give rise to a statistically significant relationship. The absence of a statistically significant relationship should not be taken to imply no association between the observation and the factor because it could be that the relationship is being masked by other factors not being taken into account or that the relationship is weak and that a larger sample would be required to detect it. The aim of this analysis was to determine what aspects of the habitat might be manipulated to reduce cormorant numbers. Consequently, only factors with strong associations with numbers would be of interest as management prescriptions based on subtle associations would be unlikely to have the required impact.

The habitat variables were considered as additional explanatory variables having, where necessary, first controlled for visit period, visit being included as a class variable to allow for seasonal differences in cormorant abundance or fluctuations due to weather conditions at the time of the visit. As is standard for count data, models assumed a Poisson distribution, and specified a log link function. The final models took the form

$$\text{LOG(NUMBER OF CORMORANTS)} = \alpha + \beta(\text{VISIT PERIOD}) + \gamma(\text{HABITAT FACTOR 1}) + \delta(\text{HABITAT FACTOR 2})$$

where α is the model intercept and β, γ and δ are parameter estimates for each factor (assuming in this example that the visit period and two habitat factors are retained by the statistical modelling process). Habitat features are sequentially added to the model, only being retained if they significantly improve the fit of the model to the observations or if, after adding further habitat features, they cannot be removed without a significant loss to the fit of the model to the observations. Any habitat factors that are retained by the modelling process are potentially important features explaining the presence or absence of cormorants.

3. RESULTS

3.1 Waterways Breeding Bird Survey

Cormorant and habitat data from the WBBS were available from 168, 182 and 161 river stretches for 1998, 1999 and 2000 respectively. There was no evidence of a difference in the occurrence of cormorants between Canal and River stretches (1998: χ^2_1=0.4322, NS; 1999: χ^2_1=0.2781, NS; 2000: χ^2_1=0.1188, NS) (Table 3.1.1).

		Canal	River	Total
No Cormorants	1998	**71**	**84**	155
	1999	**37**	**123**	160
	2000	**37**	**107**	144
Cormorants	1998	**6**	**7**	13
	1999	**5**	**17**	22
	2000	**4**	**13**	17
Total	1998	77	91	168
	1999	42	140	182
	2000	41	120	161

Table 3.1.1. Occurrence of cormorants on canals and rivers as recorded by WBBS, 1998 to 2000.

There was no evidence of a difference in the occurrence of cormorants between waterways that were dredged compared with those that were not dredged (1998: χ^2_1=0.0006, NS; 1999: χ^2_1=0.0017, NS; 2000: χ^2_1=0.0375, NS) (Table 3.1.2).

		Dredged	Not Dredged	Total
No Cormorants	1998	**150**	**5**	155
	1999	**158**	**2**	160
	2000	**143**	**1**	144
Cormorants	1998	**13**	**0**	13
	1999	**22**	**0**	22
	2000	**17**	**0**	17
Total	1998	163	5	168
	1999	180	2	182
	2000	160	1	161

Table 3.1.2. Occurrence of cormorants on waterways with and without dredging as recorded by WBBS, 1998 to 2000.

There was no evidence of a difference in the occurrence of cormorants between waterways with banks where some vegetation clearing was recorded and banks with vegetation not cleared (1998: χ^2_1=0.0023, NS; 1999: χ^2_1=0.2430, NS; 2000: χ^2_1=1.4828, NS) (Table 3.1.3).

		Some Clearance	Uncleared Vegetation	Total
No Cormorants	1998	**12**	**76**	88
	1999	**8**	**61**	69
	2000	**6**	**61**	67
Cormorants	1998	**1**	**6**	7
	1999	**2**	**10**	12
	2000	**2**	**7**	9
Total	1998	13	82	95
	1999	10	71	81
	2000	8	68	76

Table 3.1.3. Occurrence of cormorants on waterways with and without bank clearance as recorded by WBBS, 1998 to 2000.

There was no evidence of a difference in the occurrence of cormorants between waterways with dystrophic (defined as being black water), oligotrophic (clear) and eutrophic (green) water (1998: χ^2_1=0.0831, NS; 1999: χ^2_1=1.2200, NS; 2000: χ^2_1=0.5801, NS) (Table 3.1.4).

		Dystrophic (black)	Oligotrophic (clear)	Eutrophic (green)	Total
No Cormorants	1998	**18**	**49**	**24**	91
	1999	**21**	**76**	**15**	112
	2000	**17**	**70**	**16**	103
Cormorants	1998	**2**	**5**	**2**	9
	1999	**3**	**10**	**4**	17
	2000	**2**	**5**	**2**	9
Total	1998	20	54	26	100
	1999	24	86	19	129
	2000	19	75	18	112

Table 3.1.4. Occurrence of cormorants on waterways with dystrophic (defined as being black water), oligotrophic (clear) and eutrophic (green) water as recorded by WBBS, 1998 to 2000.

There was no evidence of a difference in the occurrence of cormorants between waterways that were disturbed compared with those that were not disturbed (1998: χ^2_1=1.4941, NS; 1999: χ^2_1=0.7767, NS; 2000: χ^2_1=0.7537, NS) (Table 3.1.5). For this analysis it was necessary to combine disturbance due to fishing with disturbance due to water sports and boating, as otherwise the sample size would have been too small for the individual analyses.

		Disturbed	Undisturbed	Total
	1998	**106**	**49**	155
No Cormorants	1999	**101**	**59**	160
	2000	**86**	**58**	144
	1998	**11**	**2**	13
Cormorants	1999	**16**	**6**	22
	2000	**12**	**5**	17
	1998	117	51	168
Total	1999	117	65	182
	2000	98	63	161

Table 3.1.5. Occurrence of cormorants on waterways with and without disturbance as recorded by WBBS, 1998 to 2000.

There was no evidence of a difference in the occurrence of cormorants between waterways with fast flowing water and those with slow to medium flowing water (1998: χ^2_1=0.0135, NS; 1999: χ^2_1=0.5781, NS; 2000: χ^2_1=0.5026, NS) (Table 3.1.6).

		Fast Flowing	Slow or Medium Flowing	Total
	1998	**38**	**117**	155
No Cormorants	1999	**49**	**111**	160
	2000	**46**	**98**	144
	1998	**3**	**10**	13
Cormorants	1999	**5**	**17**	22
	2000	**4**	**13**	17
	1998	41	127	168
Total	1999	54	128	182
	2000	50	111	161

Table 3.1.6 Occurrence of cormorants on fast flowing and slow or medium flowing waterways as recorded by WBBS, 1998 to 2000.

3.2 Intensive Cormorant Surveys on the River Wensum

The numbers of cormorants recorded in each 90 minute period during each site survey are shown in Appendices 2 to 5.

In order to facilitate the statistical analyses, the detailed habitat descriptions collected in the field for each pool or river stretch were reduced to a suite of simple class variables. The habitat of each pool was thus described in terms of the presence or absence of angling, the presence or absence of islands and whether or not they were stocked (Table 3.2.1).

Pool	Grid Reference (mid-point)	Angling	Island	Stocked
UP1	TF953285	NO	NO	NO
UP2	TF955282	NO	NO	NO
UP3	TF982252	NO	YES	NO
UP3A	TF974256	NO	YES	NO
SP1	TG016195	YES	YES	YES
SP1A	TG018190	YES	YES	YES
SP2	TG064185	YES	YES	YES
UP6	TG082178	NO	NO	NO
UP6A	TG075178	YES	YES	NO
SP4	TG143127	YES	NO	YES
SP5	TG158134	YES	YES	YES

Table 3.2.1. Habitat descriptors of pools. Variables represent a synthesis of the detailed habitat descriptions collected in the field.

In a similar manner, the habitat of each river stretch was described in terms of average width, flow rate, fish biomass, weed cover, bank vegetation and the presence or absence of adjacent woodland (Table 3.2.2).

River Stretch	Upstream Grid Ref	Downstream Grid Ref	Average Width (m)	Flow Rate	Fish Biomass (g/m^2)	Weed	Banks	Adjacent Woodland
OR1	TF953286	TF958281	4.5	Average	8.002	HIGH	LOW	NO
OR2	TF958279	TF964273	7.0	Slow	9.649	HIGH	LOW	NO
CR1	TF973263	TF978254	5.0	Slow	1.415	HIGH	HIGH	YES
CR2	TF978254	TF988251	5.5	Slow	1.415	HIGH	HIGH	YES
OR6	TG009195	TG016194	6.5	Slow	43.950	LOW	LOW	NO
OR7	TG016194	TG022187	6.5	Slow	18.420	LOW	HIGH	NO
OR10	TG055184	TG063187	8.5	Slow	11.850	LOW	LOW	NO
OR11	TG063187	TG069184	8.5	Slow	0.855	LOW	HIGH	NO
CR3	TG075176	TG081177	8.5	Gliding	17.050	HIGH	HIGH	NO
OR12	TG081177	TG083182	8.5	Gliding	17.050	HIGH	HIGH	NO
OR13	TG145140	TG139133	7.0	Average	5.349	LOW	LOW	YES
CR7	TG142125	TG149127	8.5	Average	5.349	HIGH	HIGH	YES
CR8	TG153132	TG160137	11.0	Gliding	14.600	HIGH	LOW	YES

Table 3.2.2. Habitat descriptors of river stretches. Fish biomass taken from EA (1997a,b,c). Remaining variables represent a synthesis of the detailed habitat descriptions collected in the field.

3.2.1 Cormorant numbers on still waters versus rivers

The generalised linear model relating the number of cormorants to type of water body indicated that still waters held a greater number of cormorants than did river stretches, having controlled for differences between visits (visit: χ^2_3=7.98, P=0.0465; water body type: χ^2_1=114.44, P < 0.0001). It should be noted that surface-area of water was not accounted for in the model, thereby modelling density of birds, because it was thought that the areas calculated would be inaccurate. The models, therefore, predict numbers of birds on a site by site basis. This may have affected the results, as some of the still waters were very large (e.g. UP3A) and would, therefore, be expected to hold more cormorants even if they were distributed randomly.

Separate generalised linear models relating the number of cormorants to habitat features were developed for still waters and river stretches. This was necessary because different habitat measurements were appropriate for the two types of water body.

3.2.2 Cormorant numbers according to riverine habitat

The generalised linear model relating the number of cormorants to habitat features associated with river stretches indicated that fewer birds were observed on river stretches with high weed growth (χ^2_1=4.41, P = 0.0357). The addition of the remaining riverine habitat features (visit, river width, flow-rate, fish biomass, cutting or otherwise of bank vegetation and the presence or absence of riverine woodland) did not add significantly to the model. There was, therefore, no evidence that any of these factors help explain the number of cormorants present.

3.2.3 Cormorant numbers according to still water habitat

The generalised linear model relating the number of cormorants to habitat features associated with still waters indicated that, having controlled for differences between visits (χ^2_1=12.86, P = 0.0050) more birds were observed on still waters with islands (χ^2_1=50.57, P < 0.0001) and where stocking has occurred (χ^2_1=6.53, P = 0.0106) but that in the presence of fishermen numbers were lower (χ^2_1=4.93, P < 0.0264).

4. DISCUSSION

Surveys conducted both along the river and at the still water sites of the Wensum Valley during the summer months showed that cormorants are not a major threat to the fishery at this time of year, as no feeding birds were recorded during daily visits to each site. Just three birds were recorded at Sennowe Park, where they were nesting in a tree on an island in still water site UP3. Some cormorants may make use of the area at this time of year, but not many.

By October, cormorants were widespread in the Wensum valley (Roy Church pers. comm.), and were present throughout the winter survey period between December and February. Still water bodies held significantly more feeding cormorants than river stretches, with still waters that were stocked holding more birds than those that were not stocked. Birds are probably attracted by the higher density of fish at some still waters, particularly those actively stocked by angling associations. However, the presence of anglers at a site caused a reduction in the number of feeding cormorants. This is to be expected as cormorants are wary of human activity and fly away at some distance to human disturbance (McKay *et al*. 1999, pers. obs.). Of the various habitat features investigated, only the presence of islands in the water body showed a significant relationship with the number of cormorants. More cormorants were found at sites with islands, probably because these provide a safe area to roost whilst not foraging (McKay *et al*. 1999), although it should be noted that it was, in general, the larger water bodies that contained islands.

Few feeding cormorants (nine sightings out of 312 samples) were recorded on the River Wensum throughout the winter. The birds that were seen feeding along the river were noted in various habitat types, although river stretches with less weed growth held significantly more feeding cormorants than stretches with higher weed growth. This may be due to the fish being more visible or easier to catch in areas where channel vegetation does not impede the cormorants. The weeds may therefore be acting as a natural "refuge" for the fish. Although it would appear that the river is not seriously threatened by cormorants it is possible that modest predation pressure could exhibit a disproportionate effect on the fragmented roach and dace populations along the Wensum. It is possible, therefore, that management to provide natural fish "refuges" could alleviate depredation of the fish stocks. WBBS data also showed that few cormorants were detected on rivers relative to the length of river surveyed, and as a result, no river feature or habitat associations could be found. Some riverine sites on the Wensum were also visited over the course of one day during very cold weather in January 2001 when the still waters were frozen over. No cormorants were observed foraging on the river then, and birds may have moved to coastal sites. Cormorants are known to move up to 70 kilometres to forage (Marquiss & Carss 1994).

Case studies on the impact of fish-eating birds at various fisheries including four riverine and four still water habitats showed that depredation by cormorants was more variable on still waters than on rivers. Rivers may, therefore, at least in the short-term, be able to buffer against bird depredation more than still waters (Feltham *et al.* 1999). As long as still waters, especially those stocked for the purposes of recreational angling, are present in the Wensum valley, and cormorant numbers do not increase dramatically, it is unlikely that they will become an increasingly serious problem on the river. At the still water fisheries, cormorants are probably already damaging angling interests, and are likely to continue to do so in the future if the inland population increases (Russell *et* al. 1996; Rehfisch *et al*. 1999). Full impact assessments would be required to determine the extent of the effect that birds are having at individual sites. Cormorant numbers have been increasing inland, both during the breeding season and the winter (Rehfisch *et al.* 1999). Inland breeding was rare in England before 1981, but increased to 1,317 pairs in 1996, a rate of increase of 60% p.a. It is thought that this has been driven by immigration of inland breeding birds, particularly of the race *sinensis*, from the European mainland. The number of wintering cormorants overall in Britain has also been increasing, possibly by 4% p.a. on average since the 1970s and 80s, although the population appears to have more or less stabilised over the last 10 years (unpublished WeBS report 2001), with the exception of inland gravel pits, where they continue to increase. Estimates of 14% increase p.a. have been given for a number of inland put-and-take fisheries between 1988-93 (Callaghan *et al.* 1994). Predictive models show that the inland population of cormorants in Britain is likely to continue to increase (Newson 2000). With an increase in the inland cormorant population, there may be increasing pressure on fisheries managers to deter cormorants from both commercial and recreational fisheries.

Cormorant deterrents

McKay *et al.* (1999) reviewed various lethal and non-lethal measures for controlling damage by fish-eating birds to inland fisheries. The review concluded that, in order to reduce numbers of birds at roosts and breeding colonies, laser light scaring at night roosts and tree removal at breeding colonies were most effective. Laser lights are expensive, however, as well as labour intensive and cutting down trees is only practicable in a limited number of situations. Due to the dangers associated with laser lights, it is also very unlikely that permission would be granted for their use. Shooting small numbers of birds, fireworks and egg-pricking were less effective. Birds that are shot or displaced in this way are often replaced by other birds, unless continuous effort is maintained. In order to prevent foraging at fish farms, protective netting covering entire pools was more effective than partial netting or wires. At angling sites, however, this is obviously not a practical option. Human disturbance was the only method found to be consistently effective at scaring or deterring birds from a site. Again, this is a labour intensive method of preventing birds from foraging and is less effective if alternative suitable foraging sites are not available. Other types of disturbance, such as gas bangers, raptors, fireworks, audio devices, scarecrows and helicopters were not as effective. Disturbed cormorants must feed somewhere else, and scaring may transfer the problem to neighbouring fisheries (Kirby *et al.* 1996, 1997), therefore in the Wensum valley, it is possible that birds will make increased use of the river, if they are actively discouraged from using the still waters.

Other management techniques were also considered, including changes in stocking regime and provision of fish refuges. The review concluded that stocking larger fish may be cost-effective and can reduce predation levels, although there may be an increased incidence of damage to fish. Fish suffering associated damage from cormorant attacks may be subject to higher mortality rates, through increased exposure to, and spread of, pathogenic and fungal infections, both between and within species. In addition to this, stocking larger fish may be viable for salmonids, but problems could be encountered with some coarse fish, such as roach and perch, which would be unlikely to be large enough to be stocked at the sizes required. These species, which are popular with anglers, could therefore decline within the fishery, if attempts were made to stock fish of larger sizes. In experiments at pools in Hertfordshire, cormorant dive durations were longer and bird-inflicted injury was significantly lower in trials with refuges provided than when they were not (McKay *et al*. in prep.). Provision of fish refuges may, therefore, reduce the availability of fish to foraging cormorants. More research is required to develop refuges that are effective at deterring cormorants, while allowing angling activities to continue.

5. RECOMMENDATIONS FOR FURTHER WORK

1. Despite the very low numbers observed, there was indication that cormorants feeding on the river favoured areas with less weed growth. Intensive monitoring of alternate river stretches with high and low weed growth, in areas where cormorants are most abundant, would be necessary to further investigate this relationship. Where possible, video cameras could be used to monitor the river stretches, in order to avoid causing disturbance, which was found to reduce the number of cormorants present at a site.

2. In addition to the above, trials using fake vegetation in the river, which may act as a “refuge” for fish, could be carried out, to determine whether it is possible to discourage cormorants from foraging in potentially suitable areas. This could be done by monitoring a suitable river stretch for 5 days without the fake weed in place, followed by 5 days with the weed installed, and then repeating this protocol. Again, if all of the experimental site is visible from one vantage point, video recorders could be used, to avoid discouraging the birds through disturbance.

3. Experiments into the response of cormorants to stocking regimes could be carried out. This would require the monitoring of a sample of sites immediately before and after stocking, and estimating the off-take by cormorants. This could help identify when stocked sites are most in need of protection.

4. A review of the literature regarding cormorant foraging techniques and site preference, with particular reference to the site factors identified in this study: weed growth (and possibly water turbidity), disturbance, islands and stocking regime.

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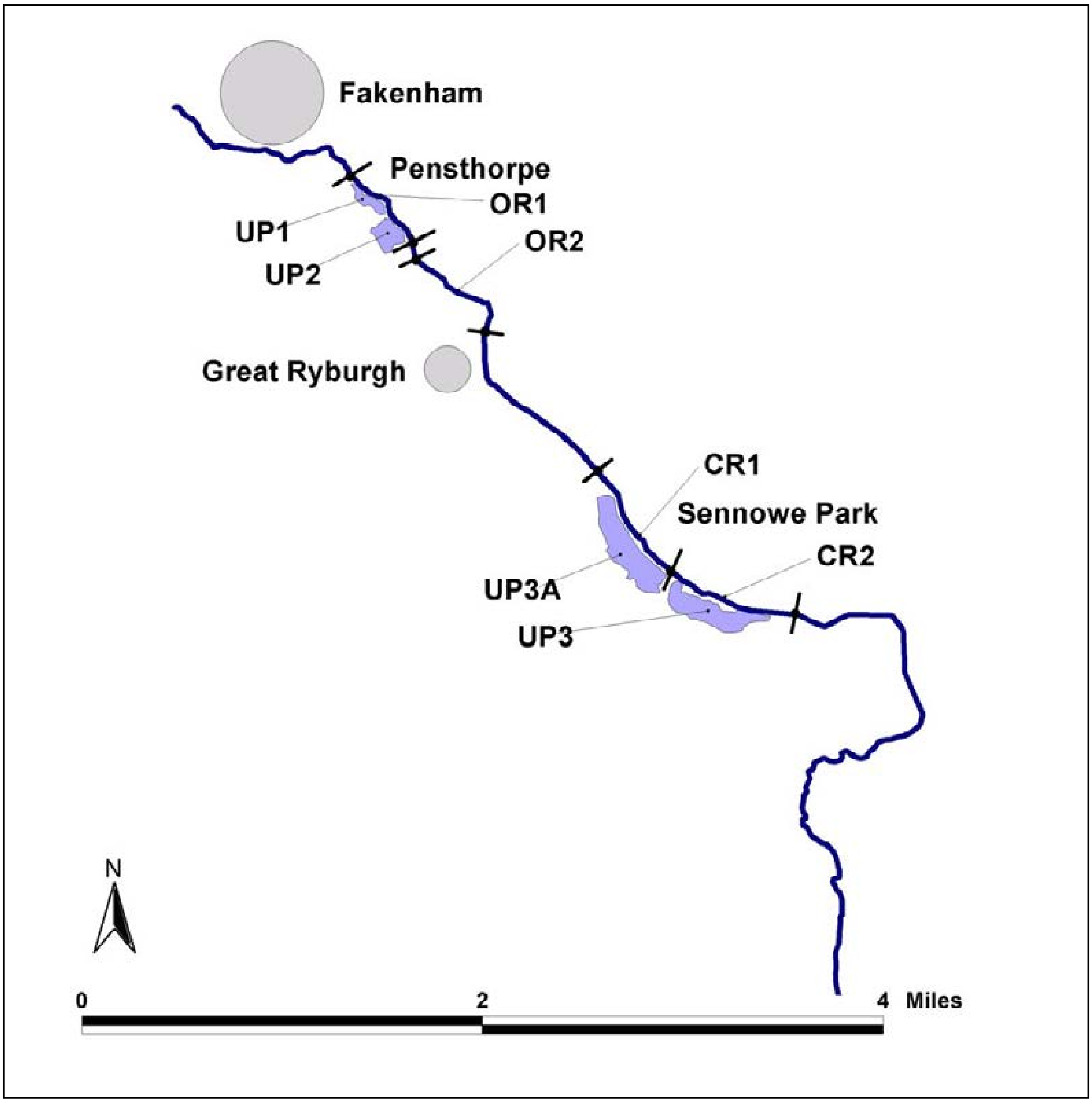

Figure 2.2.1.1 Cormorant survey sites in the upper Wensum Valley

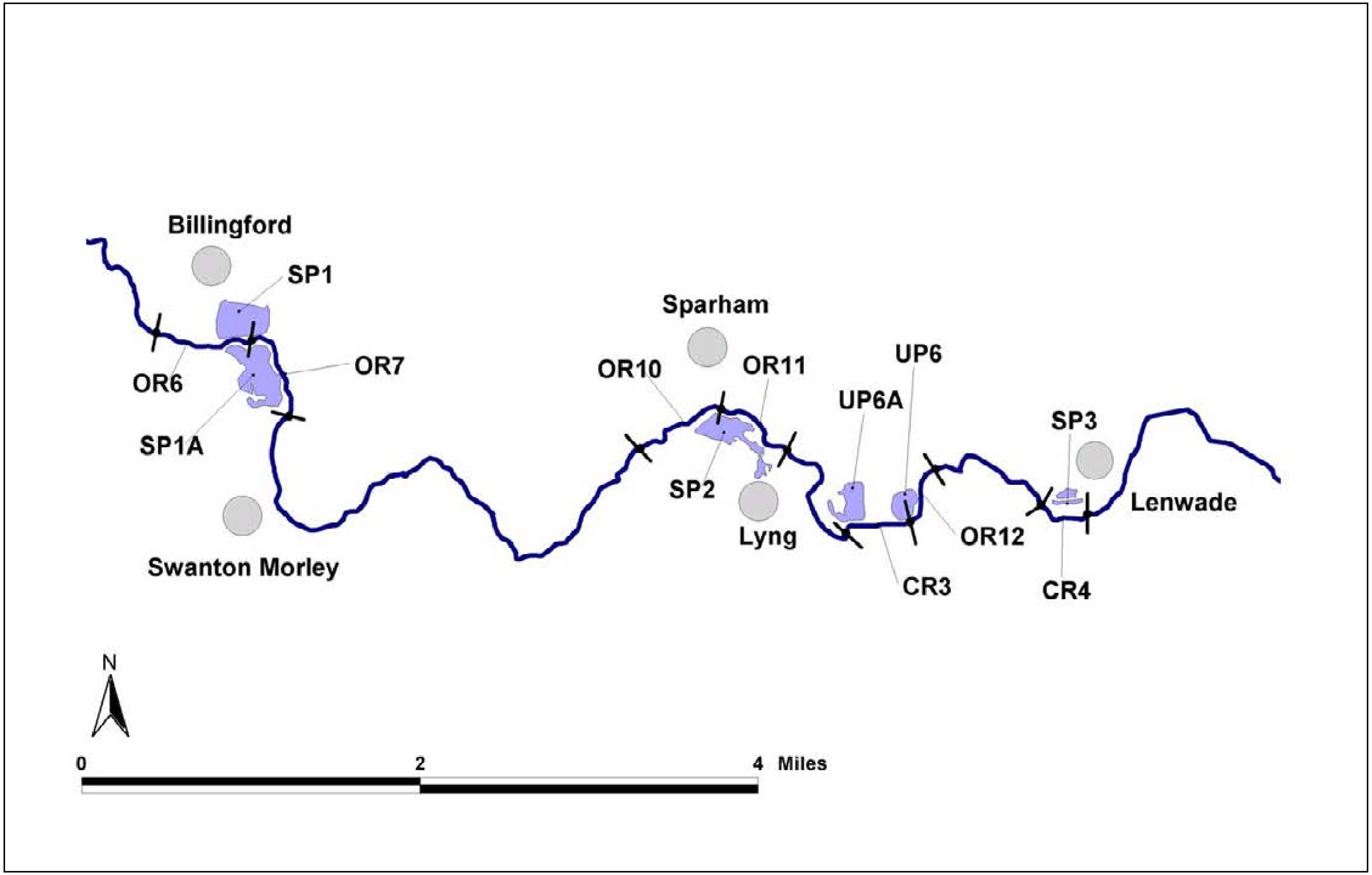

Figure 2.2.1.2 Cormorant survey sites in the middle Wensum Valley.

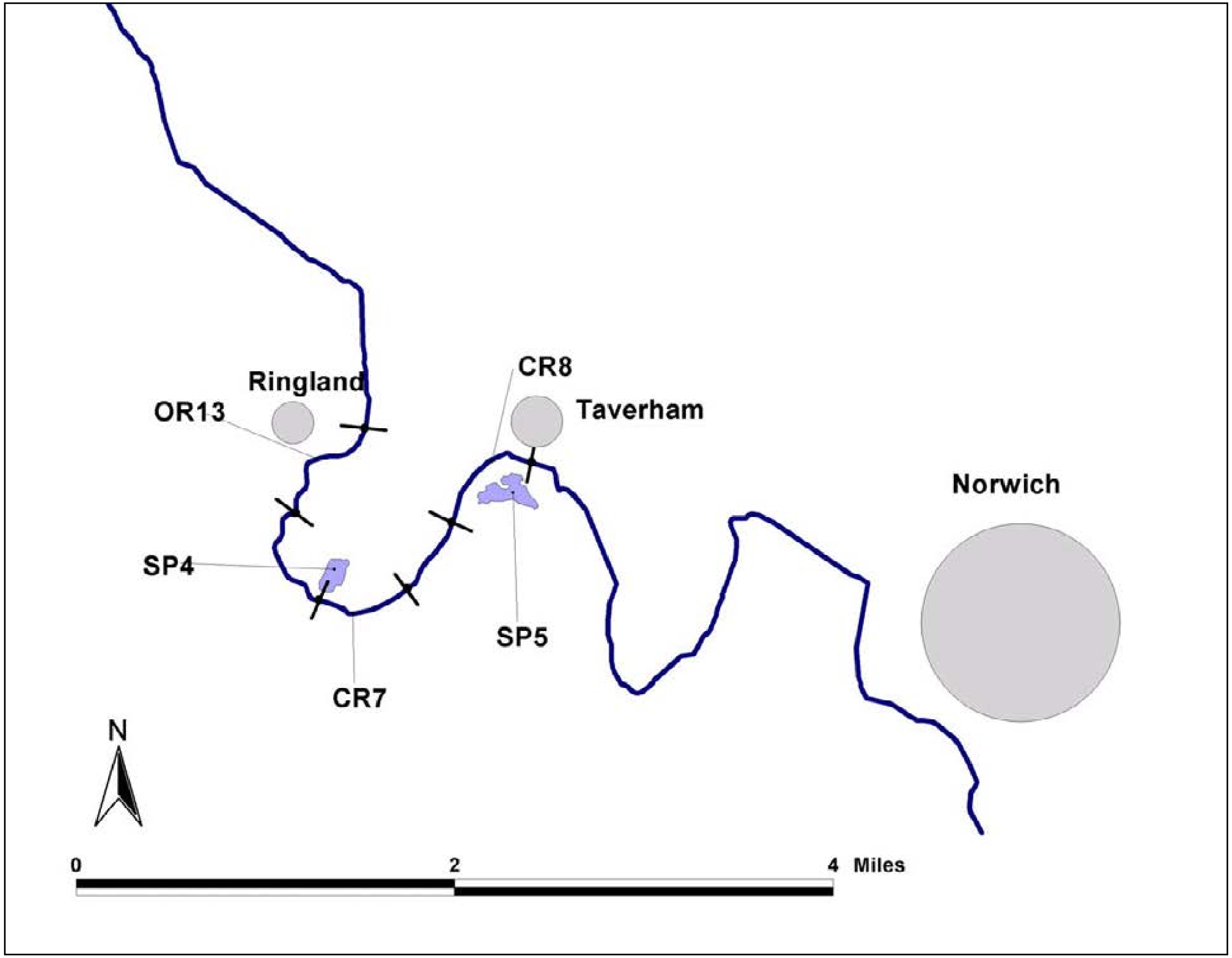

Figure 2.2.1.3 Cormorant survey sites in the lower Wensum Valley.

Appendix 1 Habitat recording codes used for WBBS survey. N.B. Level 3 codes within each group are mutually exclusive. Groups are separated by a space.

BTO HABITAT CODING SCHEME

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4*
A WOODLAND	**1** Broadleaved **2** Coniferous **3** Mixed (10% of each) **4** Broadleaved water-logged **5** Coniferous water-logged **6** Mixed water-logged	**1** Mixed-aged or semi-natural **2** Coppice with standards **3** Coppice without standards **4** Mature plantation (taller than 10m, with closed canopy) **5** Young plantation (5-10m, open canopy) **6** Parkland (scattered trees and grassy areas) **7** High-medium disturbance from people **8** Low disturbance **9** Near road (within 50m)	**1** Dense shrub layer **2** Moderate shrub layer **3** Sparse shrub layer **4** Dense field layer **5** Moderate field layer **6** Sparse field layer **7** Grazed (moderate to heavy) **8** Lightly grazed **9** Dead wood present **10** Dead wood absent
B SCRUBLAND (or young woodland <5m tall)	**1** Regenerating natural or semi-natural woodland **2** Downland (chalk) **3** Heath scrub **4** Young coppice **5** New plantation **6** Clear-felled woodland with or without new saplings **7** Other	**1** Broadleaved **2** Coniferous **3** Mixed (10% of each) **4** Broadleaved swamp scrub **5** Coniferous swamp scrub **6** Mixed swamp scrub **7** High-medium disturbance from people **8** Low disturbance **9** Near road (within 50m)	**1** Predominantly tall (3-5m) **2** Predominantly low (1-3m) **3** Dense shrub layer **4** Moderate shrub layer **5** Sparse shrub layer **6** Extensive bracken **7** Dense field layer **8** Moderate field layer **9** Sparse field layer **10** Grazed (moderate to heavy)
C SEMI-NATURAL GRASSLAND /MARSH	**1** Chalk downland **2** Grass moor (unenclosed) **3** Grass moor mixed with heather (unenclosed) **4** Machair **5** Other dry grassland **6** Water-meadow/ grazing marsh **7** Reed swamp **8** Other open marsh **9** Saltmarsh	**1** Hedgerow with trees **2** Hedgerow without trees **3** Tree-line without hedge **4** Other field boundary (wall, ditch, etc.) **5** Isolated group of 1-10 trees **6** No field boundary **7** Montane **8** High-medium disturbance from people **9** Low disturbance **10** Near road (within 50m)	**1** Ungrazed **2** Cattle **3** Sheep **4** Horses **5** Rabbits **6** Deer **7** Other grazers **8** Extensive bracken **9** Hay
D HEATHLAND AND BOGS	**1** Dry heath **2** Wet heath **3** Mixed heath **4** Bog **5** Breckland **6** Drained bog **7** Bare peat	**1** Montane **2** Raised bog **3** Valley/ basin bog **4** Blanket bog **5** Heath mixed with rough grass **6** Heath without grass **7** Heath with extensive bracken **8** Undetermined bog **9** Isolated group of 1-10 trees **10** Disturbance from people **11** Low disturbance **12** Near road (within 50m)	**1** Ungrazed **2** Cattle **3** Sheep **4** Horses **5** Rabbits **6** Deer **7** Other grazers **8** Ploughed **9** Burned **10** Planted with saplings less than 0.5m tall
E FARMLAND	**1** Improved grassland **2** Unimproved grassland **3** Mixed grass/ tilled land **4** Tilled land **5** Orchard **6** Other farming	**1** Hedgerow with trees **2** Hedgerow without trees **3** Tree-line without hedge **4** Other field boundary (wall, ditch, etc.) **5** Isolated group of trees **6** Farmyard (active) **7** Near road (within 50m) **8** No field boundary	**1** Ungrazed **2** Cattle **3** Sheep **4** Horses **5** Other stock **6** Bare earth/plough **7** Autumn cereal **8** Spring cereal **9** Root crops (specify) **10** Other crops (specify) **11** Oil seed rape **12** Other brassicas (specify) **13** Stubble (clean) **14** Stubble (weedy) **15** Unsown/Fallow **16** Recently cut grass
F HUMAN SITES	**1** Urban **2** Suburban **3** Rural	**1** Building **2** Gardens **3** Municipal parks/ mown grass/ golf courses/ recreational areas **4** Sewage works "urban" **5** Near road (within 50m) **6** Near active railway line (within 50m) **7** Other **8** Rubbish tip	**1** Industrial **2** Residential **3** Well-wooded **4** Not well-wooded **5** Area of large gardens **6** Area of medium gardens **7** Area of small gardens **8** Many shrubs **9** Few shrubs **10** Disused
G WATER BODIES (freshwater)	**1** Pond (less than $50m^2$) **2** Small water-body ($50-450m^2$) **3** Lake/unlined reservoir **4** Lined reservoir **5** Gravel pit, sand pit, etc **6** Stream (less than 3m wide) **7** River (more than 3m wide) **8** Ditch with water (less than 2m wide) **9** Small canal (2-5m wide) **10** Large canal (more than 5m wide)	**1** Undisturbed/ disused **2** Water sports (sailing etc) **3** Angling (coarse or game) **4** Coarse angling **5** Game fishing **6** Industrial activity **7** Sewage processing 'rural' **8** Other disturbance **9** Small island	**1** Eutrophic (green water) **2** Oligotrophic (clear water, few weeds) **3** Dystrophic (black water) **4** Marl (clear water, large water-weeds) **5** Slow-medium running **6** Fast-running **7** Dredged **8** Undredged **9** Banks cleared **10** Banks vegetated
H COASTAL	**1** Marine - open shore **2** Marine shore - inlet/cove/ loch **3** Estuarine **4** Brackish lagoon **5** Open sea	**1** Mud or silt **2** Sand **3** Shingle **4** Rocky **5** Fully vegetated **6** Sparse/medium vegetation **7** Inter-tidal **8** Below low-water mark	**1** Cliff vertical/ steeply sloping **2** Dune **3** Flat/gently sloping **4** Small island **5** Spit **6** Dune slack **7** Sloping ground **8** Undisturbed **9** Disturbed
I INLAND ROCK	**1** Cliff **2** Scree/boulder slope **3** Limestone pavement **4** Other rock outcrop **5** Quarry **6** Mine/spoil/ slag heap **7** Cave	**1** Active **2** Disused **3** Montane **4** Non-montane **5** High disturbance from climbers/ walkers etc. **6** Medium disturbance **7** Low disturbance	**1** Bare rock **2** Low vegetation present (mosses, liverworts, etc) **3** Grasses present **4** Scrub present

Appendix 2 Numbers of cormorants recorded in each 90 minute period during the first site surveys.

Site	Date	07.30-09.00	09.00-10.30	10.30-12.00	12.00-13.30	13.30-15.00	15.00-16.30
UP1	29-Dec	0	0	0	0	0	0
UP2	29-Dec	0	0	0	0	0	0
OR1	29-Dec	0	0	0	0	0	0
OR2	29-Dec	0	0	0	0	0	0
UP3	20-Dec	6	3	2	2	6	2
UP3A	20-Dec	2	4	2	3	1	1
CR1	20-Dec	0	0	0	0	0	0
CR2	20-Dec	0	0	0	0	0	0
SP1	18-Dec	7	4	1	3	2	1
SP1A	18-Dec	0	3	0	1	0	0
OR6	18-Dec	0	0	0	0	0	0
OR7	18-Dec	0	0	0	0	0	0
SP2	11-Jan	2	0	1	0	0	1
OR10	11-Jan	0	0	0	0	0	0
OR11	11-Jan	0	0	1	0	0	0
UP6	11-Jan	0	1	0	0	0	0
UP6A	11-Jan	0	0	0	0	0	1
CR3	11-Jan	0	0	0	0	0	0
OR12	11-Jan	0	0	0	0	0	0
OR13	15-Dec	0	0	0	0	0	0
SP4	15-Dec	0	0	0	0	0	0
CR7	15-Dec	0	0	0	0	0	0
CR8	15-Dec	0	0	0	0	0	0
SP5	15-Dec	3	2	2	1	1	2

Appendix 3 Numbers of cormorants recorded in each 90 minute period during the second site surveys.

Site	Date	07.30-09.00	09.00-10.30	10.30-12.00	12.00-13.30	13.30-15.00	15.00-16.30
UP1	10-Jan	0	0	0	0	0	0
UP2	10-Jan	0	0	0	0	0	0
OR1	10-Jan	1	0	0	0	0	0
OR2	10-Jan	0	0	0	0	0	0
UP3	19-Jan	0	0	0	0	0	0
UP3A	19-Jan	1	0	2	2	1	0
CR1	19-Jan	0	0	0	0	0	0
CR2	19-Jan	0	0	0	0	0	0
SP1	14-Jan	4	0	0	5	0	0
SP1A	14-Jan	0	0	0	0	0	0
OR6	14-Jan	0	0	0	0	0	0
OR7	14-Jan	0	2	0	0	0	0
SP2	12-Jan	3	1	0	0	0	0
OR10	12-Jan	0	0	1	0	0	0
OR11	12-Jan	0	0	0	0	0	0
UP6	12-Jan	0	0	0	0	0	0
UP6A	12-Jan	0	0	0	1	0	0
CR3	12-Jan	0	0	0	0	0	0
OR12	12-Jan	0	0	0	0	0	0
OR13	26-Jan	0	0	0	0	0	0
SP4	26-Jan	0	0	0	0	0	0
CR7	26-Jan	1	1	0	0	0	0
CR8	26-Jan	0	0	0	0	0	0
SP5	26-Jan	2	1	1	1	0	1

Appendix 4 Numbers of cormorants recorded in each 90 minute period during the third site surveys.

Site	Date	07.30-09.00	09.00-10.30	10.30-12.00	12.00-13.30	13.30-15.00	15.00-16.30
UP1	04-Feb	0	1	0	0	0	0
UP2	04-Feb	0	0	0	0	0	0
OR1	04-Feb	0	0	0	0	0	0
OR2	04-Feb	0	0	0	0	0	0
UP3	31-Jan	2	2	3	4	3	5
UP3A	31-Jan	0	3	6	4	2	4
CR1	31-Jan	0	0	0	0	0	0
CR2	31-Jan	0	0	0	0	0	0
SP1	06-Feb	12	3	2	0	1	0
SP1A	06-Feb	3	1	0	0	0	0
OR6	06-Feb	0	0	0	0	0	0
OR7	06-Feb	0	0	0	0	0	0
SP2	21-Jan	3	2	0	0	0	0
OR10	21-Jan	0	0	0	0	0	0
OR11	21-Jan	0	0	0	0	0	0
UP6	21-Jan	0	0	0	1	0	0
UP6A	21-Jan	0	0	0	0	0	2
CR3	21-Jan	0	0	0	0	0	0
OR12	21-Jan	0	0	0	0	0	0
OR13	07-Feb	0	0	1	0	0	0
SP4	07-Feb	0	0	0	0	1	0
CR7	07-Feb	0	0	0	0	0	0
CR8	07-Feb	0	0	0	0	0	0
SP5	07-Feb	4	2	3	2	2	2

Appendix 5 Numbers of cormorants recorded in each 90 minute period during the final site surveys.

Site	Date	07.30-09.00	09.00-10.30	10.30-12.00	12.00-13.30	13.30-15.00	15.00-16.30
UP1	08-Feb	0	0	0	0	0	0
UP2	08-Feb	0	0	0	0	0	0
OR1	08-Feb	0	0	0	0	0	0
OR2	08-Feb	0	0	0	0	0	0
UP3	15-Feb	3	3	2	1	0	2
UP3A	15-Feb	0	4	2	2	0	4
CR1	15-Feb	0	0	0	0	0	0
CR2	15-Feb	0	0	0	0	0	0
SP1	19-Feb	5	2	2	2	0	3
SP1A	19-Feb	3	1	1	0	0	0
OR6	19-Feb	0	0	0	0	0	0
OR7	19-Feb	0	0	0	0	0	0
SP2	02-Feb	3	1	1	0	0	2
OR10	02-Feb	0	0	0	0	0	0
OR11	02-Feb	0	1	0	0	0	0
UP6	02-Feb	0	1	0	0	1	0
UP6A	02-Feb	2	0	0	2	0	0
CR3	02-Feb	0	0	0	0	0	0
OR12	02-Feb	0	0	0	0	0	0
OR13	13-Feb	0	0	0	0	0	0
SP4	13-Feb	0	1	0	0	0	1
CR7	13-Feb	0	0	0	0	0	0
CR8	13-Feb	0	0	0	0	0	0
SP5	13-Feb	4	1	2	1	2	1