An assessment of cormorant depredation on stillwater coarse fish populations in the Lea and Colne valleys of the Thames catchment

Environment Agency
Hertfordshire and Middlesex Wildlife Trust
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An assessment of cormorant depredation on stillwater coarse fish populations in the Lea and Colne valleys of the Thames catchment

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Statement of use
This report will be used to update fisheries managers within the Agency on the current understanding of the impacts of cormorants on the on stillwater coarse fish populations in the Lea and Colne valleys of the Thames catchment. It will also be used along with complimentary MAFF, DETR and Environment Agency funded work on fish-eating birds (currently under progress) to assist the Agency in improving its policy and management practises with respect to cormorant depredation at freshwater fisheries.

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EXECUTIVE SUMMARY

In response to concerns over the adverse effects of cormorant depredation at freshwater fisheries the Agency commissioned R&D Project No.596 'An assessment of cormorant depredation on stillwater coarse fish populations in the Lea and Colne valleys of the Thames catchment'. The one year project was carried out between October 1995 and October 1996 and comprised (i) an experiment to assess the impact of cormorants at a small stocked lagoon and (ii) a questionnaire survey of the perceived impact of cormorants on the fish stocks of stillwaters in part of the Thames catchment.

The programme of research was carried out by the Thames Region of the Environment Agency (the Agency) and two contractors, the Hertfordshire & Middlesex Wildlife Trust (HMWT) and Dr Mark J. Feltham (MJF). Their respective roles were as follows; the Agency carried out the questionnaire survey and all fisheries work at the experimental site, HMWT carried out all bird counts and bird observations at the experimental site and MJF analysed all data and produced the final report.

The impact experiment was carried out at the Rye Meads lagoon complex (NGR TL388103) in the Lea Valley, Hertfordshire. Two small lagoons (≈0.3 ha) were stocked in October 1995 with similar numbers, lengths and weights of three cyprinid species (roach *Rutilus rutilus*, bream *Abramis brama* and carp *Cyprinus carpio)* at approximately 180 kg ha^{-1}. One lagoon (control) was entirely covered in 2.5 cm black nylon netting and the other (test) lagoon was left unnetted.

Cormorant *Phalacrocorax carbo* occupancy was monitored during 36 visits to the site during the following six months (winter period) after which both lagoons were drained. All surviving fish were removed, counted, measured and checked for damage. Both lagoons were then refilled and stocked with similar numbers, lengths and weights of new fish in April 1996. The lagoons were then similarly monitored for six months (summer period) and drained down in October 1996.

Despite a year round presence of cormorants at Rye Meads the number of birds using the test lagoon were low. A peak of 3.5 birds d^{-1} was recorded during November 1995 (about 30 days post- stocking), after which the numbers dropped abruptly to between 0.0 - 0.5 birds d^{-1} for the remainder of the winter. Numbers peaked again following stocking in April 1996 at 3.0 birds d^{-1} before declining to between 0.0 - 1.7 birds d^{-1} for the remainder of the summer.

A total of 303 hours observations were carried out at the test lagoon during which only 29 cormorant feeding bouts took place. These typically lasted 5-6 mins with the birds diving on average twice a minute and staying underwater, typically for between 8 - 18 seconds. During observed feeding bouts a total of 339 dives were recorded but only 12 fish were seen to be caught. All fish were between 5 - 10 cm in length, except for one 23 cm carp.

Fish mortality in the test lagoon was assessed at the end of the winter and summer periods and found to be 89.1% and 95.2%, respectively. In the control lagoon mortality was 35.8% and 37.8% for the respective periods and represented natural post-stocking mortality due to it's enclosed nature. This was, rather alarmingly, found not to be unusually high compared to some Dutch studies that have commonly reported > 75%

post-stocking mortality of some cyprinids. Taking post-stocking mortality into account, therefore, 52.5% of winter stock and 57.3% of summer stock from the test lagoon could have been lost to predators.
Although theoretical considerations about the daily food intake of cormorants suggested they could quite easily have removed these fish, feeding observations data showed that only a small proportion (6.7%) of the loss could clearly be attributed to cormorants. The majority of fish loss (> 48%) could not.

Two alternative hypotheses (i) cormorants swallowing fish underwater and (ii) nocturnal depredation by herons were, therefore, proposed to try to account for the remaining losses. Neither, unfortunately, could be substantiated in this study, although the latter receives some support in the scientific literature whilst the former does not. The remaining uncertainty regarding the major source of mortality at the site should, therefore, be well noted. In addition, it is important that the 'natural' post-stocking mortality of species such as roach and bream should be taken into account when assessing losses to a fishery and that serious consideration should be given to whether stocking these species is appropriate.

The second part of the study was a questionnaire survey of stillwaters in the Lea and Colne valleys. This was carried out during 1996 to compliment the experimental work at the Rye Meads lagoons. Questionnaires were sent to each of approximately 350 angling clubs / fisheries owners asking for information on; (i) cormorant presence (typical numbers and when birds were seen) (ii) any perceived depredation (numbers, sizes and species of fish taken) (iii) changes in the numbers, sizes and species of fish caught by pleasure and/or match anglers (iv) details of fish stocked (v) the availability of historic match weight data and (vi) when cormorants were first noticed at their sites.

8.4% of questionnaires were returned and analysed. These contained 141 records from 110 stillwater sites (equivalent to about 25% of the 400+ angled waters in the region). Almost 75% of sites surveyed appeared to have had cormorants for > 3 years and relatively few respondents reported recent colonization. Larger waterbodies typically contained the most birds, but the numbers of birds reported from small waters (< 5 ha) varied enormously, from 1-4 birds upto 50+.

Occupancy of stillwater sites by cormorants showed clear seasonal and diurnal trends. Most respondents reported winter occupancy at their waters and fewest reported summer occupancy. Only 16.2% of respondents claimed to have cormorants on their waters year round. Cormorants were reported to visit sites mostly between dawn - 10am (83.8% of respondents) although birds were present at many sites during other parts of the day.

Cormorants were reported to take roach most often followed by bream, rudd carp, perch and trout. Dace, crucians, tench, chub and eel were reported only infrequently as prey items. The most commonly reported size of fish taken by cormorants was 10 - 20 cm. 3.3% of respondent reported that although cormorants were present at their sites they were not observed taking fish, 15.5% reported that cormorants typically ate 1 - 2 fish per visit, 16.4% stated 3 - 4 fish and 16.4% stated 4+ fish. The remaining respondents were unable to specify the numbers of fish eaten by these birds.

Only 38.7% of respondents had catch records, yet the vast majority of reports claimed a reduction in the numbers of fish being caught both by pleasure anglers (82% of records) and match anglers (89.4%) during the past 2-3 years. 38% of pleasure anglers reported catching larger fish and 42% reported catching smaller fish than 2 - 3 years ago, whilst almost twice as many match anglers reported catching larger fish (63%) compared to those catching smaller fish (30%).

The questionnaire survey showed there has been a perceived shift in the species caught by anglers in the Lea and Colne valleys in recent years, **from** roach, small-medium sized bream, perch and rudd **to** carp (particularly large ones), tench and large bream. The reasons for these changes appear to be due to a number of interacting factors including (i) the species being stocked in the area (ii) bird depredation and (iii) differential mortality of wild and stocked fish.

This could have serious implications for fisheries in the Lea and Colne valleys because the above factors may lead to the eventual predominance of very robust species e.g. carp at the expense of other, less robust species popular among anglers e.g roach, rudd and small bream. This presents fishery owners with somewhat of a dilemma; if the magnitude of post-stocking mortality of small roach and bream is high and, in addition, the mortality of these species from a variety of bird predators is similar, continued stocking with these fish is unlikely to benefit the fishery. Conversely the increasing practice of stocking large carp could eventually result in the serious degradation of many small stillwaters. Active bottom feeding by these fish and others such as large bream will result in an increase in year round water turbidity, the loss of submerged plant-life and the loss of more fragile fish species which cannot compete. In short, an attempt to promote stillwater angling by stocking large 'predator proof' species could in the medium to long term do more harm to a fishery than the predators could do alone.

KEY WORDS

CORMORANT IMPACT, CYPRINID, EXPERIMENT, ANGLERS, QUESTIONNAIRE SURVEY, PISCIVORY.

(L.), bream *Abramis brama* (L.), roach *Rutilus rutilus* (L.), crucian carp *Carassius carassius* (L.), rudd *Scardinius erythrophthalmus* (L.), perch *Perca fluviatilis*, chub *Leuciscus leuciscus* and eel *Anguilla anguilla* (L.) have all been recorded from the lagoons (Saunders 1995). The test of effluent ceased at the site in the 1970's since when many of the lagoons became the focus of fish population studies (e.g. Colclough 1980, White and Williams 1977, both cited in Saunders 1995). These studies highlighted the potential of the site for fish rearing and in 1992 a three year rolling programme was initiated by the former NRA to realise this.

Work began initially on two lagoons, No.8 (control) and No.9 (test) (Figure 1.2). After the resident fish had been removed and the lagoons had been drained and left dry (to oxidise the silt and kill any parasites) the lagoons were refilled and stocked (Saunders 1995). Between 15th April 1993 and 27th September 1994 a total of 4261 fish of between 5 - 15 cm, were stocked. 1550 rudd and 250 tench were stocked in lagoon No.9 and 1570 roach, 450 tench, 392 bream and 49 barbel *Barbus barbus* (L.) were stocked in lagoon No.8. Regular visits to the two lagoons, however, suggested that the numbers of fish appeared to be declining. In December 1994 therefore, the two lagoons were comprehensively netted. Only one rudd, two roach and three tench were caught. Heavy depredation was suggested as one explanation for these observations and cormorants as one possible source of this depredation given that they had been observed on Lagoon No.8 between 1993 - 1994 (Saunders, A. personal communication) and had been observed taking part in a 'feeding frenzy' at the Northern lagoons during September 1995 (Roper, P. personal communication). During the latter, five cormorants were observed to begin feeding on 10 - 29 cm common and mirror carp during a heavy shower, the fish apparently being attracted to the surface by the rain. The birds hunted primarily by swimming on the surface with their heads submerged rather than by pursuit diving as is usually the case. One bird was seen to catch at least six fish within about four minutes and all birds stopped feeding when the rain stopped.

Given the increasing number of reports of cormorant damage to fish stocks received by the Agency from angling clubs across the country, a second part of the R&D project focussed on the collection of written responses from anglers with respect to cormorant depredation at freshwater fisheries. A questionnaire was devised and circulated to 350 clubs, to enable the semi-quantitative analysis of these data to be undertaken. In this way, anglers' views from a number of stillwater locations could be represented and any trends examined in order to facilitate the comparison of quantitative and qualitative information. The overall aim of the study was, therefore, (i) to produce empirically derived estimates of cormorant impact on fish stocks by comparing fish loss in two adjacent lagoons, one protected by anti-predator netting, the other not, and (ii) to place this experiment in a broader context by reporting on a questionnaire survey of the perceived impact of these birds at other stillwater sites in the Lea and Colne Valleys.

2.0 AN EXPERIMENT TO ASSESS THE IMPACT OF CORMORANTS AT A SMALL STOCKED LAGOON

2.1 Methods

2.1.1 Site preparation

Two small lagoons (Figure 1.2) were used as test and control lagoons, respectively. Each lagoon was approximately 70 m x 40 m (≈ 0.3 ha) with sloping, raised grass banks, and an average depth of approximately 1.5 m. Both lagoons were drained in June 1995 and left empty to dry out for two months prior to refilling with water from another lagoon in August 1995. The control lagoon was entirely netted from the ground in 2.5 cm black nylon netting set approximately 1.5 m above water level. The test lagoon was left unnetted. Both lagoons were then stocked with fish.

2.1.2 Fish stocking

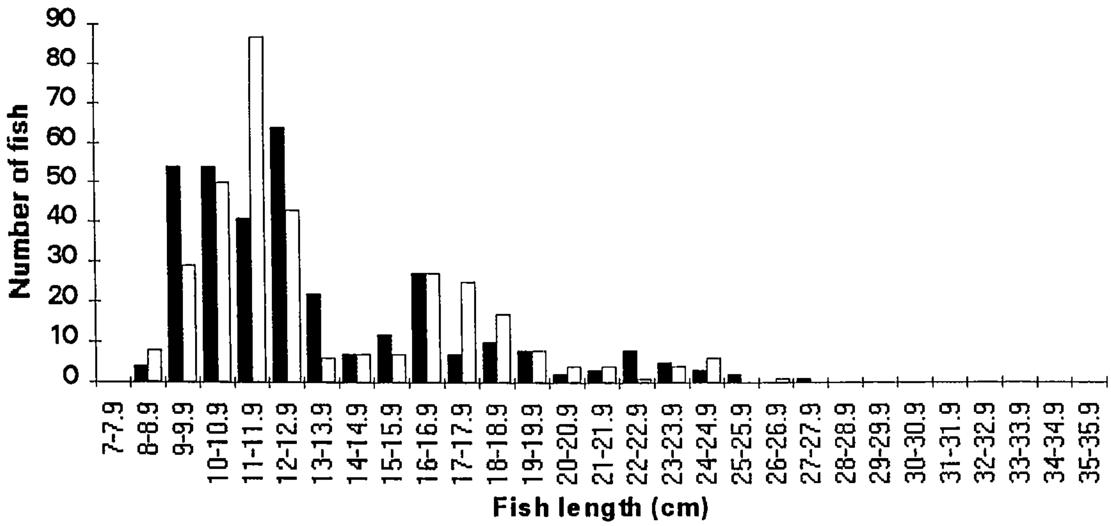
Each lagoon was stocked over a two day period (12th - 13th October 1995) with similar numbers, lengths and weights of three cyprinid species; roach, bream and carp (Figures 2.1 - 2.3). Approximately 54 kg of fish were stocked in each lagoon yielding a stocking density of approximately 180 kg ha^{-1}. The stocking density was set at a level which attempted to mirror the average stocking density of a stillwater pleasure fishery. Stocking densities in angled stillwaters vary substantially in the Thames catchment from as low as 50 kg ha^{-1} to as high as 1000 kg ha^{-1} in some commercial day ticket fisheries (Pilcher personal observation) Any dead fish seen floating on the surface during the first few weeks post-stocking were removed with hand nets. Both test and control lagoons were left for six months and drained down during 11th - 12th April 1996. All surviving fish were removed, counted, measured to the nearest millimetre and checked for damage. Both lagoons were then refilled and stocked with similar numbers, lengths and weights of new fish on 15th - 16th April 1996 (Figures 2.1-2.3). The lagoons were then left for a further six months before a final drain down on October 5th 1996. The experiment comprised, therefore, two six month periods, the first starting with an autumn stocking and continuing over the winter and the second starting with a spring stocking and continuing over the summer. These two experimental periods will be referred to hereafter, simply as the summer and winter periods.

2.1.3 Bird observations

Data on cormorant abundance at the whole Rye Meads lagoon complex were available from weekly counts at the site throughout the two study periods. These data were collected by the Rye Meads Ringing Group and made available via the Hertfordshire and Middlesex Wildlife Trust (HMWT). The latter were, however, responsible for monitoring cormorant occupancy specifically at the test lagoon.

During the winter period HMWT observations on the test lagoons began 30 days post- stocking. The lagoons were monitored for 38 randomly chosen four hour observation sessions during the 180 day experimental period. These sessions typically extended from dawn to midday or midday to dusk so that as much of the total daylight

Winter period



Summer period

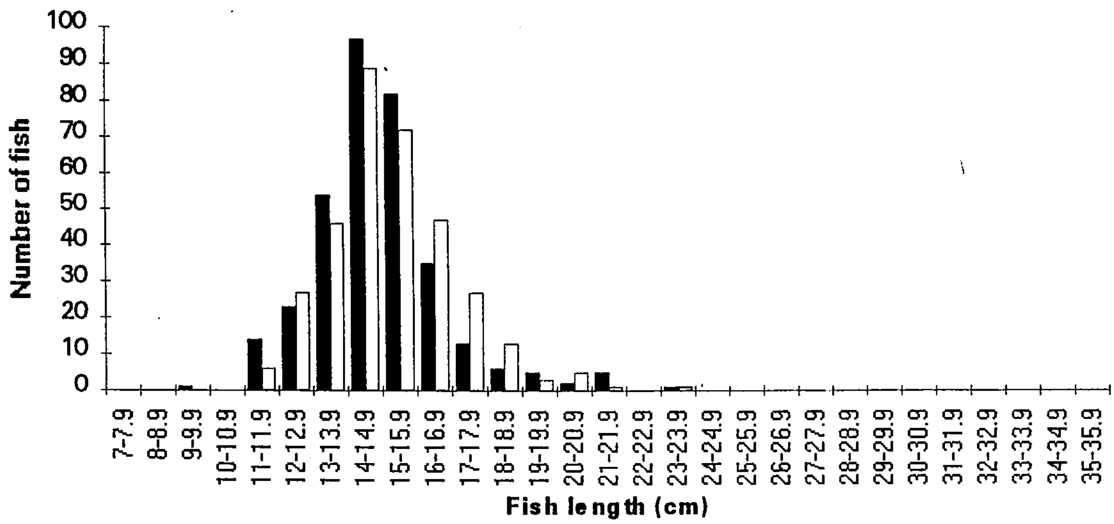
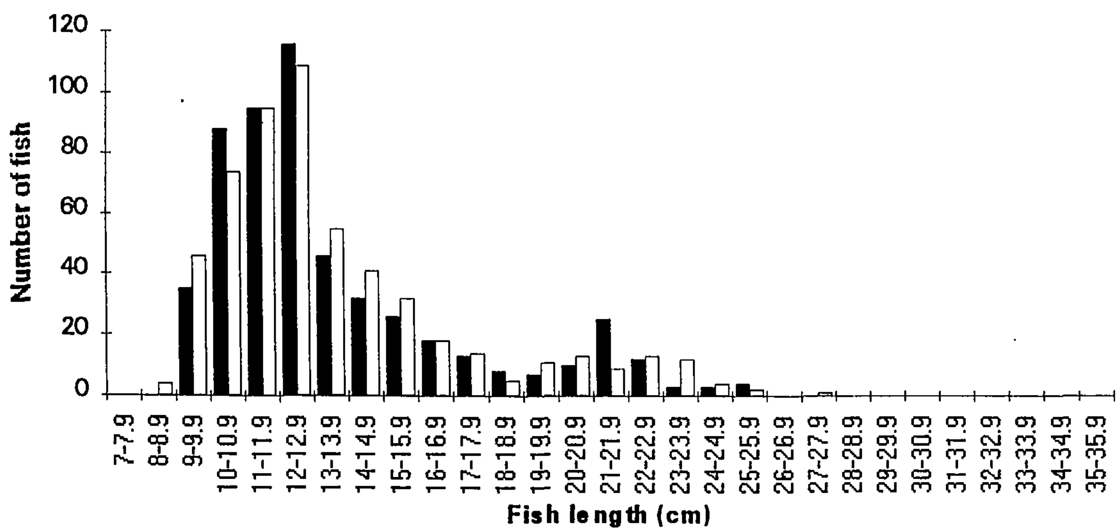


Figure 2.1. The numbers and sizes of bream *Abramis brama* put into two lagoons mid-October 1995 (winter period) and mid-April 1996 (summer period). The control lagoon (■) was covered with anti-predator netting and the test lagoon (□)was left uncovered.

Winter period



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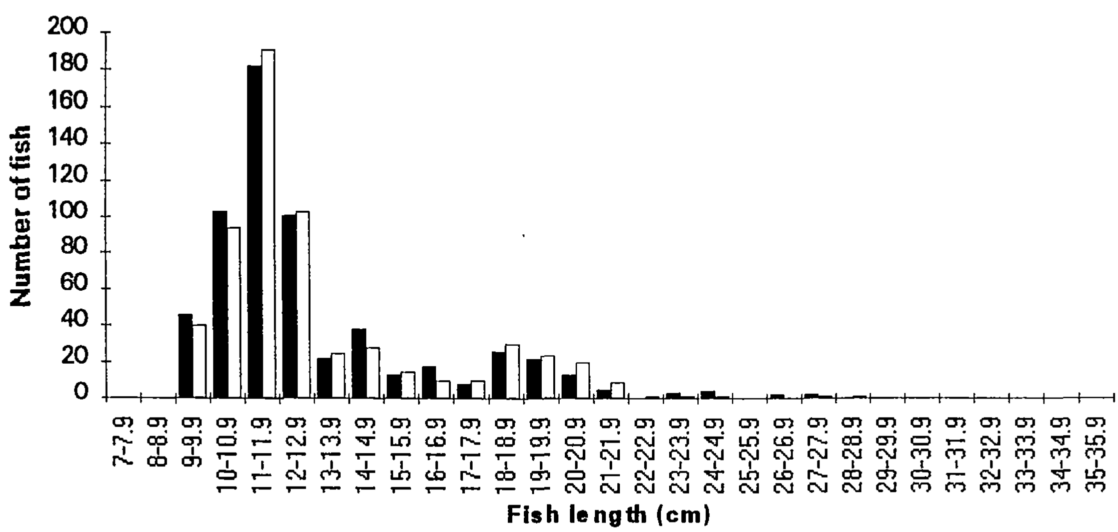
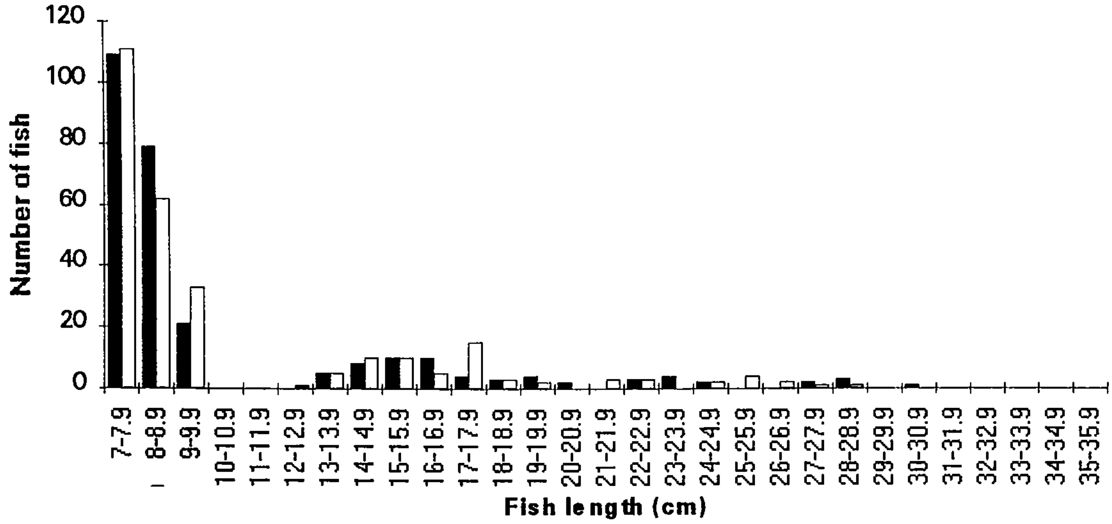


Figure 2.2. The numbers and sizes of roach *Rutilus rutilus* put into two mid-October 1995 (winter period) and mid-April 1996 (summer period). The control lagoon (■) was covered with anti-predator netting and the test lagoon (□) was left uncovered.

Winter period



Summer period

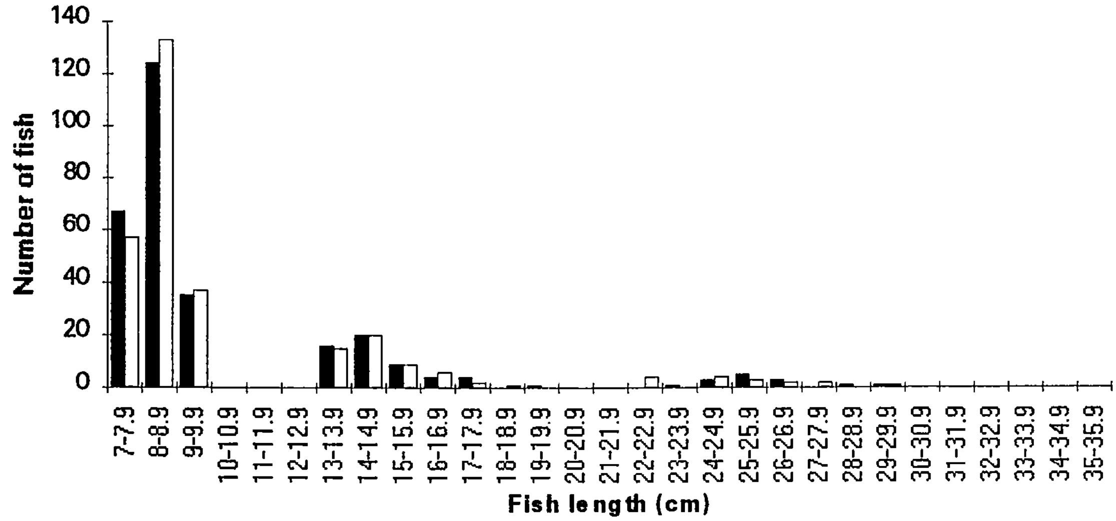


Figure 2.3. The numbers and sizes of carp *Cyprinus carpio* put into two lagoons mid-October 1995 (winter period) and mid-April 1996 (summer period). The control lagoon (■) was covered with anti-predator netting and the test lagoon (□) was left uncovered.

available to feeding cormorants was sampled. Cormorant occupancy and behaviour data at the test lagoon were available therefore for 152 hours (8.7%) of the 1758 hours of daylight available during the winter six month test period. The arrival and departure times of birds using the unnetted (test) lagoon were noted together with information on the bird's feeding behaviour. Data on individual feeding bouts were therefore recorded for each bird feeding at the site and included wherever possible; number of dives, duration of individual dives (secs), dive success (%) and the number and sizes (cm) of fish caught. Species identification was for the most part unreliable and so no attempt is made in the analyses to relate direct observations of birds to particular fish species. Other data collected during each observation session included; the numbers of cormorants overflying the test lagoons, their direction of flight (North, South etc), the time at which they were observed and the presence of any other avian or mammalian piscivores at the site.

In addition to the HMWT monitoring, Agency staff carried out approximately seven *ad hoc* one hour observations sessions at the test lagoons between October 17th and November 30th 1995 i.e. between 4 and 48 days post-stocking. In total. therefore, there were 159 hours of observations at the lagoons during the winter period, equivalent to 9.0% of available daylight hours.

During the summer period HMWT collected the same data as detailed above during 36 four hour observation sessions. Observations began two days post-stocking but because of the extended daylight hours were concentrated primarily around dawn and dusk. Cormorant occupancy and behaviour data at the test lagoon were available therefore for 144 hours (5.7%) of the 2514 hours of daylight available during the summer six month test period. There were no EA observations during this period of the study.

2.2 Results

2.2.1 Fish mortality and survival

Winter period (October 1995 - April 1996)

The number of dead fish recovered from the surfaces of the two lagoons during the first few weeks post-stocking was small; 67 fish (5.4% of the original stock) from the netted (control) lagoon and only three fish (<1% of the original stock) from the unnetted (test) lagoon respectively (Table 2.1). Nonetheless, the large proportion of fish that were unaccounted for in the control lagoon after draining suggested that post-stocking mortality was high. Over 40% of roach and bream were absent from the control lagoon (255 and 137 fish respectively) and this could not be attributed to cormorants or any other fish predator because of the enclosed nature of the lagoon. The carp stocked during the experiment, however, appeared to be more robust, particularly the larger fish (Table 2.1, Figures 2.4 - 2.6) with only 52 fish (17% of those stocked) unaccounted for. In total, therefore, 35.8% of the original stocked fish were unaccounted for, which, due to the enclosed nature of the control lagoon could not be attributed to cormorants. In addition to the differences observed in the proportions of each species recovered from the control lagoon after draining, proportionately fewer small fish of all species were recovered compared with those originally stocked (Figures 2.4 - 2.6).

Table 2.1. Winter mortality and survival of bream, roach and carp in the two test lagoons. Fish were stocked mid-October 1995 and the numbers remaining counted in mid-April 1996 after draining. [1]Natural mortalities removed with hand nets during the first few weeks immediately after stocking.

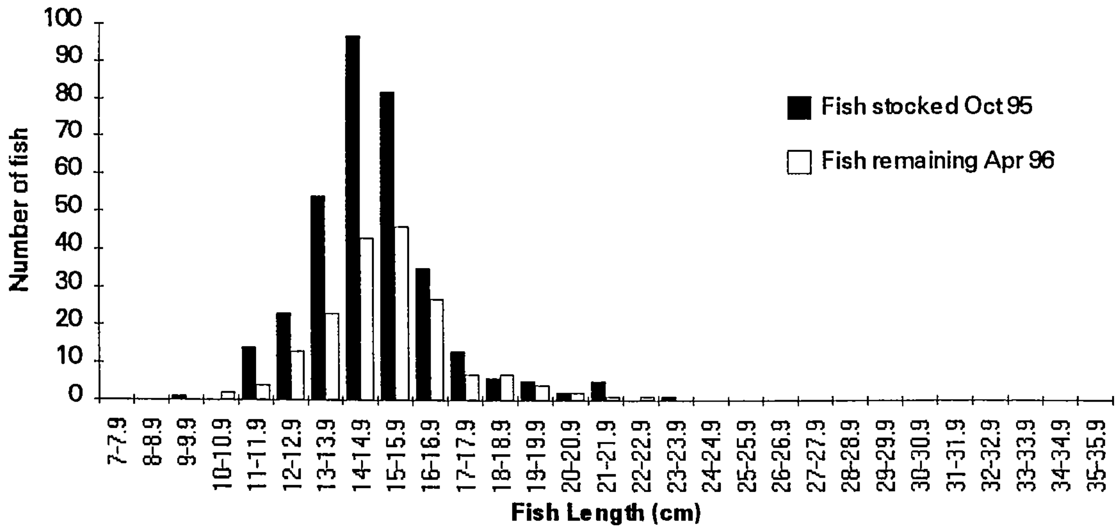
(a) Control lagoon

	Number of fish stocked	[1]Number of dead fish removed from surface of lagoon	Number of fish remaining after draining	Total number of fish accounted for (%)	Total number of fish 'unaccounted' for (%)
Bream	338	21	180	201 (59.5)	**137 (40.5)**
Roach	608	46	307	353 (58.1)	**255 (41.9)**
Carp	294	0	242	242 (82.3)	**52 (17.7)**
TOTAL	1240	67	729	796 (64.2)	**444 (35.8)**

(b) Test lagoon

	Number of fish stocked	[1]Number of dead fish removed from surface of lagoon	Number of fish remaining after draining	Total number of fish accounted for (%)	Total number of fish 'unaccounted' for (%)
Bream	337	0	1	1 (0.3)	**336 (99.7)**
Roach	604	0	53	53 (8.8)	**551 (91.2)**
Carp	243	3	72	75 (30.9)	**168 (69.1)**
TOTAL	1184	3	126	129 (10.9)	**1055 (89.1)**

Control lagoon



Test lagoon

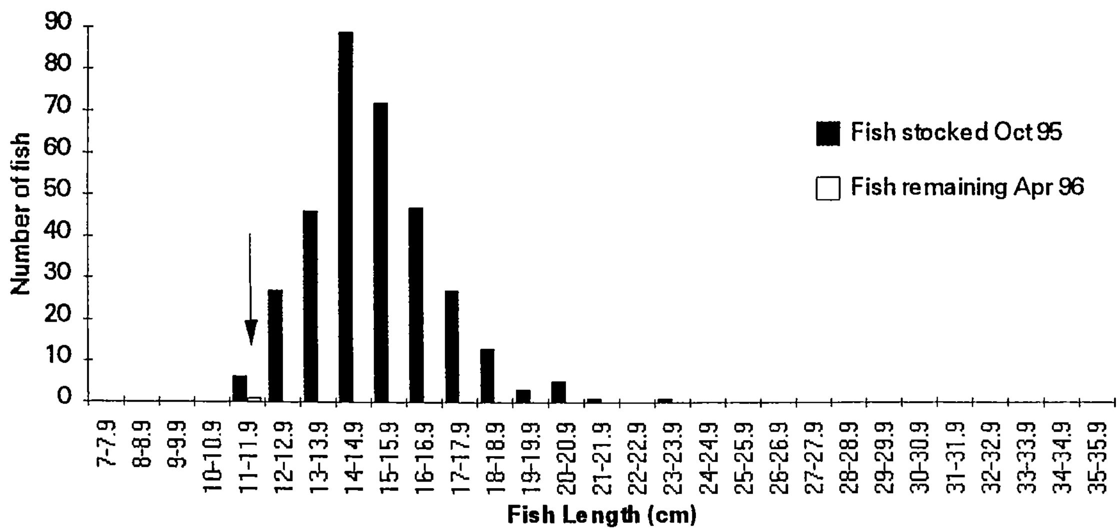
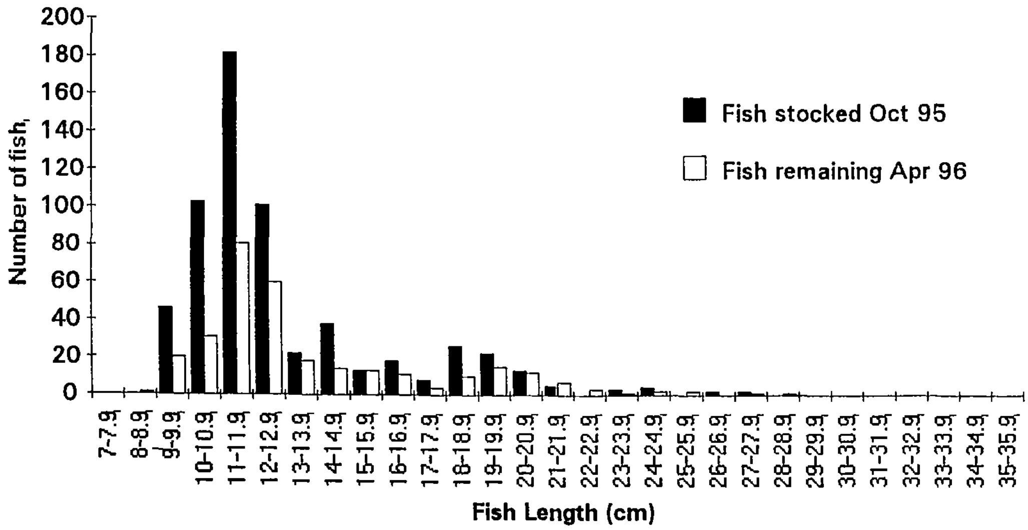


Figure 2.4. The numbers and sizes of bream *Abrama bramis* put into two lagoons mid-October 1995 and those present on draining the lagoons six month later in April 1996. Solid arrow highlights remaining small bream in test lagoon.

Control lagoon



Test lagoon

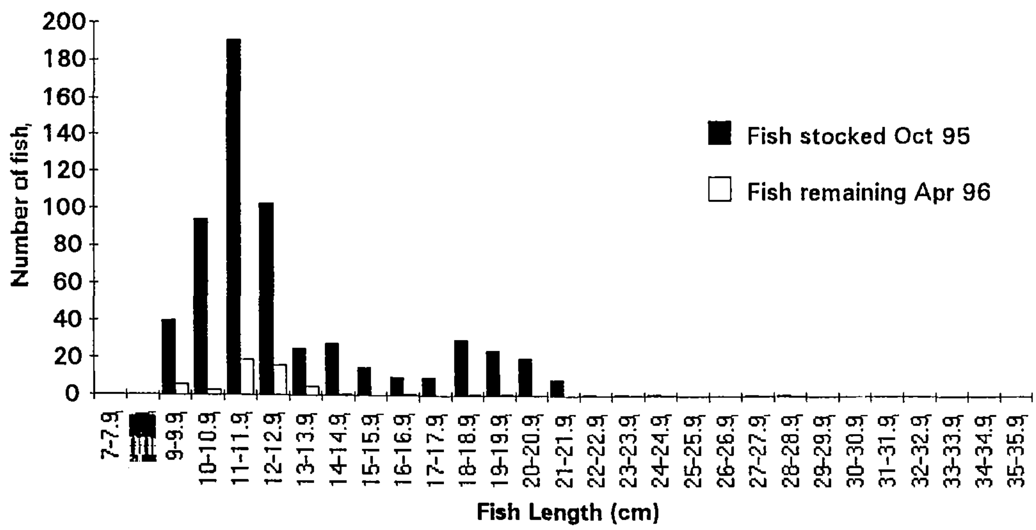
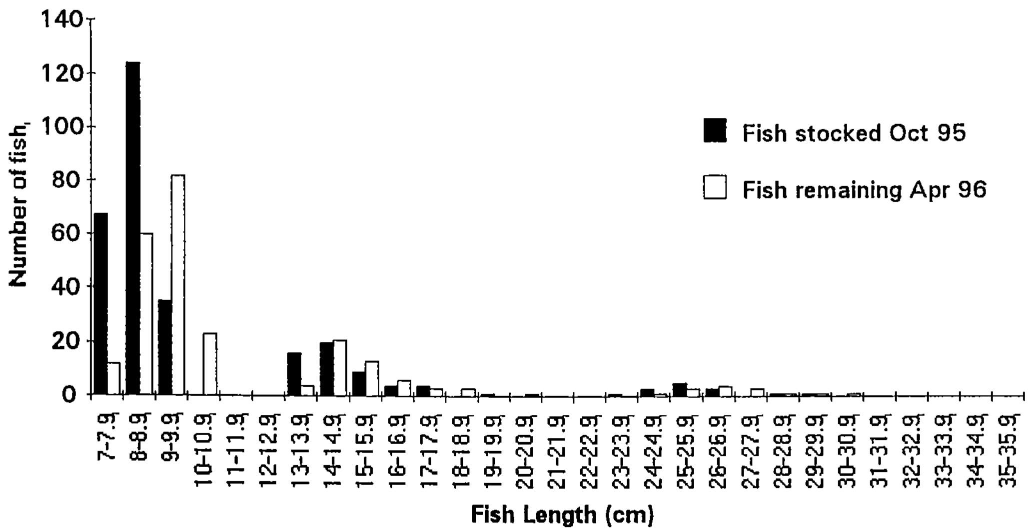


Figure 2.5. The numbers and sizes of roach *Rutilus rutilus* put into two lagoons mid-October 1995 and those present on draining the lagoons six month later in April 1996.

Control lagoon



Test lagoon

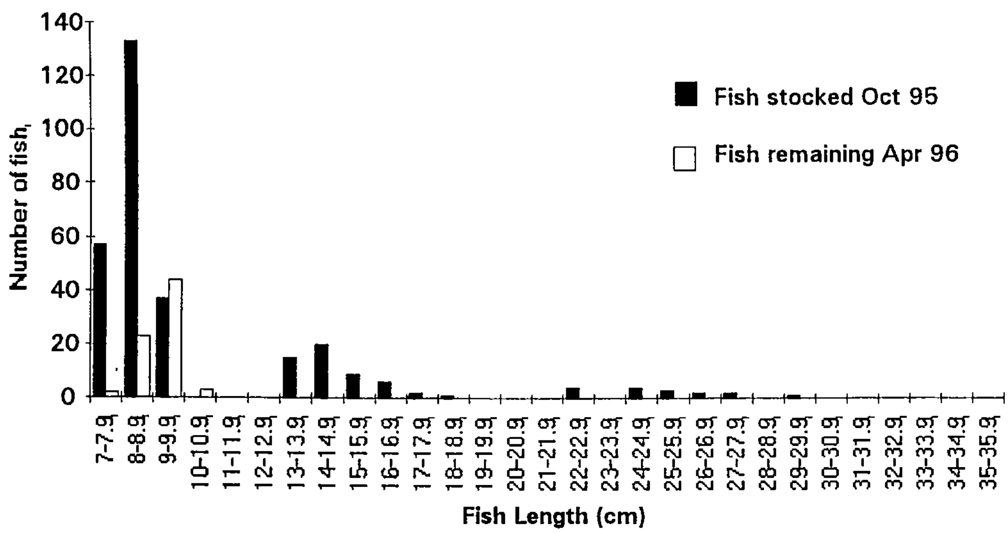


Figure 2.6. The numbers and sizes of carp *Cyprinus carpio* put into two lagoons mid-October 1995 and those present on draining the lagoons six month later in April 1996.

These data strongly suggest the majority of fish that were unaccounted for in the control lagoon had died and sank to the bottom where they were quickly lost in the sediments. Post-mortems on samples of fish recovered from both the control and test lagoons did not yield any obvious signs of disease or unusual parasite burdens. Instead, it seems likely that small roach and bream may be particularly susceptible to handling stress and that this may have indirectly reduced the survival of the stocked fish by rendering them more susceptible to fungal or bacterial infection. Indeed, other studies (Riemens 1985, Riemens 1984) have suggested that even heavier post-stocking mortality may not be uncommon in some species. If this is the case the implications for stocking still waters with these species are considerable and could lead to serious overestimates of the losses of these species attributed to piscivores (see Section 2.3).

Notwithstanding the marked mortality in the control lagoon, the almost complete absence from the test lagoon of roach (91.2% missing) and bream (99.5% missing) and the substantially reduced numbers of carp suggested that mortality due to depredation by piscivores was pronounced and was, moreover, of a similar or greater magnitude to other causes of mortality. An estimate of the fish mortality potentially attributable to cormorants was derived, therefore, by calculating the proportions of each species unaccounted for in the control lagoon and subtracting these values from the corresponding values from the test lagoon. Taking into account control lagoon mortality in this way yielded the following estimates of the potential winter loss of fish from the test lagoon to cormorants; 199 bream (59.0% of stock), 298 roach (49.3% of stock) and 125 carp (51.4% of stock). During the winter period in total therefore, 622 fish (52.5% of stock) from the unnetted (test) lagoon could have been eaten by these birds.

Summer period (April 1996 - October 1996)

As with the winter period the number of dead fish recovered from the surfaces of the two lagoons during the first few weeks post-stocking were few; 32 fish (2.8% of the original stock) from the netted (control) lagoon and 27 fish (2.3% of the original stock) from the unnetted (test) lagoon respectively (Table 2.2). Post-stocking mortality in the control lagoon was, however, again high for roach (273 fish, 50.5% of stock) and bream (134 fish, 40.1% of stock) but less for carp (26 fish, 9.6% of stock). In total, therefore, 37.8% of the original stocked fish were unaccounted for, which, due to the enclosed nature of the control lagoon could not be attributed to fish predators. Again post-mortem revealed nothing unusual.

Although summer post-stocking mortalities in the control lagoon were broadly comparable to those reported above for the winter period, during the summer there was also evidence of fish growth and recruitment (Figures 2.4 - 2.9). In addition to surviving stocked fish, 385 0+ roach, 164 0+ bream and 18 0+ carp were recovered from the control lagoon after summer drain down. In the test lagoon only 30 additional 0+ fish were recovered (eight roach and 22 carp, respectively). It was not possible to tell whether smaller size classes of fish suffered proportionately more post-stocking mortality than large fish (as appeared to be the case during the winter) because of the summer growth experienced by all species, particularly carp (Figures 2.7 - 2.9).

Taking into account control lagoon mortality in the way described in Section 1.2.1(i) above yielded the following estimates of the loss of fish from the test lagoon potentially attributable to cormorants during the summer; 265 roach (47.5% of stock), 184 bream (55.1% of stock) and 219 carp (80.2% of stock). During the summer period in total therefore, 668 fish (57.3% of stock) in the unnetted (test) lagoon could have been eaten by these birds.

Seasonal differences

There were no significant differences in the mortality of bream in the control lagoon between the winter and summer periods ($\chi^2_1 = 0.02$, ns) but proportionately more roach died during the summer ($\chi^2_1 = 8.37$, $p < 0.01$). Carp however, suffered significantly less mortality in the control lagoon during the summer compared to the winter ($\chi^2_1 = 5.89$, $p < 0.05$). Conversely, carp appeared to suffer proportionately greater depredation during the summer compared to the winter periods ($\chi^2_1 = 15.96$, $p < 0.01$), presumably as a result of their tendency to bask near the surface during warm weather, but there were no such differences in the proportions of roach and bream depredated during the two periods ($\chi^2_1 = 3.50$, ns and $\chi^2_1 = 0.13$, ns for roach and bream, respectively).

2.2.2 Cormorant abundance

Seasonal variation

The numbers of cormorants present on the Rye Meads site as a whole (estimated from weekly counts by the local ringing group) and those overflying the test lagoons (from HMWT counts) both followed the typical annual pattern reported in other studies (e.g. Davies 1997, Cowx *et al.* 1996). The numbers of birds peaked at 24-30 in January before declining to a low of between two to six during April, May and June (Figure 1.10) when birds typically return to coastal breeding grounds. During late summer and early autumn their numbers increased again as birds began to move inland to overwinter (Figure 2.10).

The first cormorant visits to the test lagoon during the winter and summer periods were recorded by Agency staff during *ad hoc* observations at the site prior to the full monitoring programme at 14 and 15 days post-stocking respectively, yet despite the year round presence of cormorants in the study area the numbers of birds using the test lagoon were low. Estimates of the mean daily number of birds using the lagoon were obtained as follows. The number of birds feeding in the test lagoon during any particular four hour observation session was converted to birds hr^{-1}. The average of these data for a particular month was then calculated and multiplied by the number of hours of daylight for that month (i.e dawn - dusk, from sunrise - sunset tables) to derive an estimate of the average number of birds per day using the site each month. Although the underlying trend in the numbers of cormorants using the test lagoon was broadly similar to the local trend in cormorants numbers (i.e. high winter counts, low summer counts) the former showed two clear peaks in each of the months following stocking of the test lagoons (Figure 2.11). The first peak occurred during November 1995 after the October stocking. A mean occupancy of 3.5 birds d^{-1} was recorded, after which the number of birds using the lagoon dropped abruptly and remained at between 0.0 - 0.5 birds d^{-1} for the remainder of the winter period

Table 2.2. Summer mortality and survival of bream, roach and carp in the two lagoons. Fish were stocked mid-April 1996 and the numbers remaining counted in mid-April October after draining. [1]Observed mortalities removed with hand nets during the first few weeks after stocking.

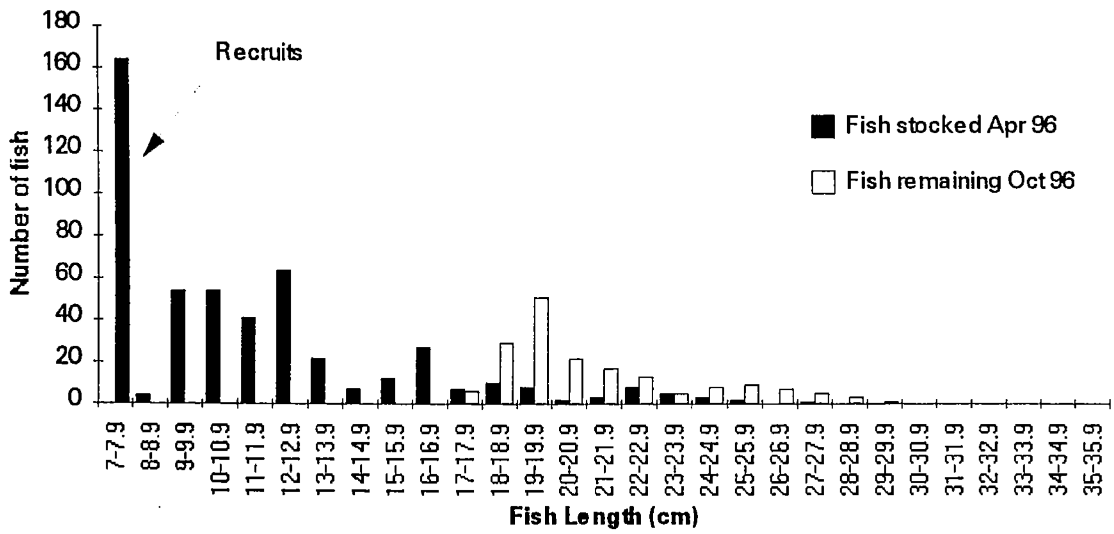
(a) Control lagoon

	Number of fish stocked	[1]Number of dead fish removed from surface of lagoon	Number of fish remaining after draining	Total number of fish accounted for (%)	Total number of fish 'unaccounted' for (%)
Bream	334	24	176	200 (59.9)	**134 (40.1)**
Roach	541	8	260	268 (49.5)	**273 (50.5)**
Carp	270	0	244	244 (90.4)	**26 (9.6)**
TOTAL	1145	32	680	712 (62.2)	**433 (37.8)**

(b) Test lagoon

	Number of fish stocked	[1]Number of dead fish removed from surface of lagoon	Number of fish remaining after draining	Total number of fish accounted for (%)	Total number of fish 'unaccounted' for (%)
Bream	334	15	1	16 (4.8)	**318 (95.2)**
Roach	558	10	1	11 (2.0)	**547 (98.0)**
Carp	273	2	26	28 (10.3)	**245 (89.7)**
TOTAL	1165	27	28	55 (4.7)	**1110 (95.2)**

Control lagoon



Test lagoon

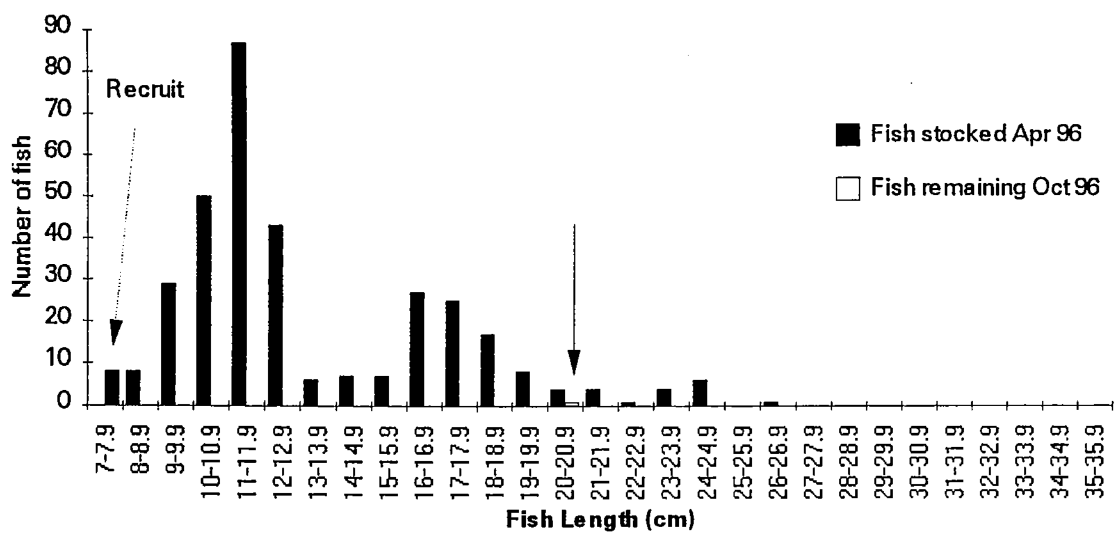
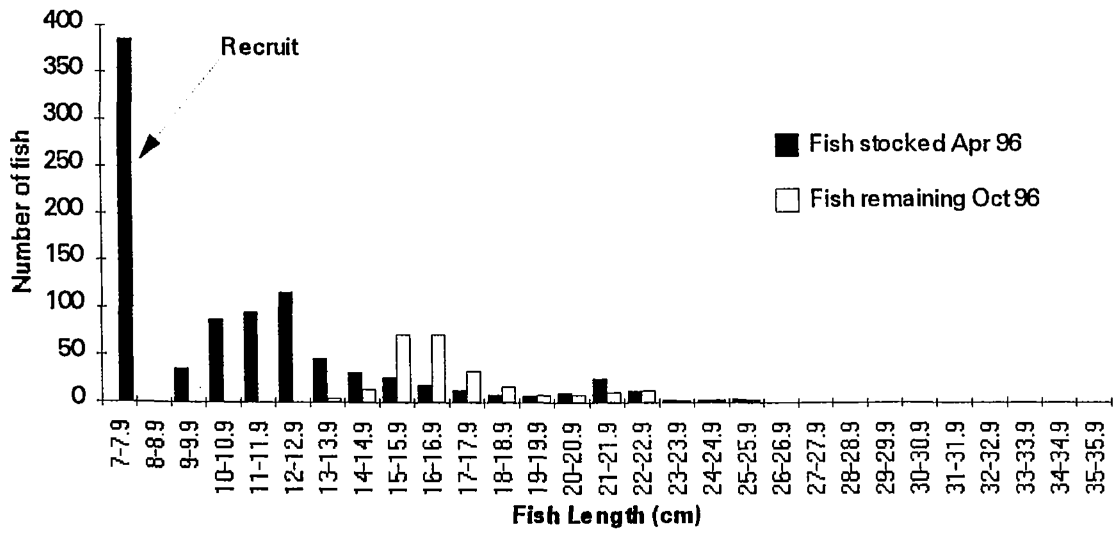


Figure 2.7. The numbers and sizes of bream *Abrama bramis* put into two lagoons mid-April 1996 and those present on draining the lagoons six month later in October 1996. Solid arrow highlights remaining small bream in test lagoon, dotted arrow new recruits.

Control lagoon



Test lagoon

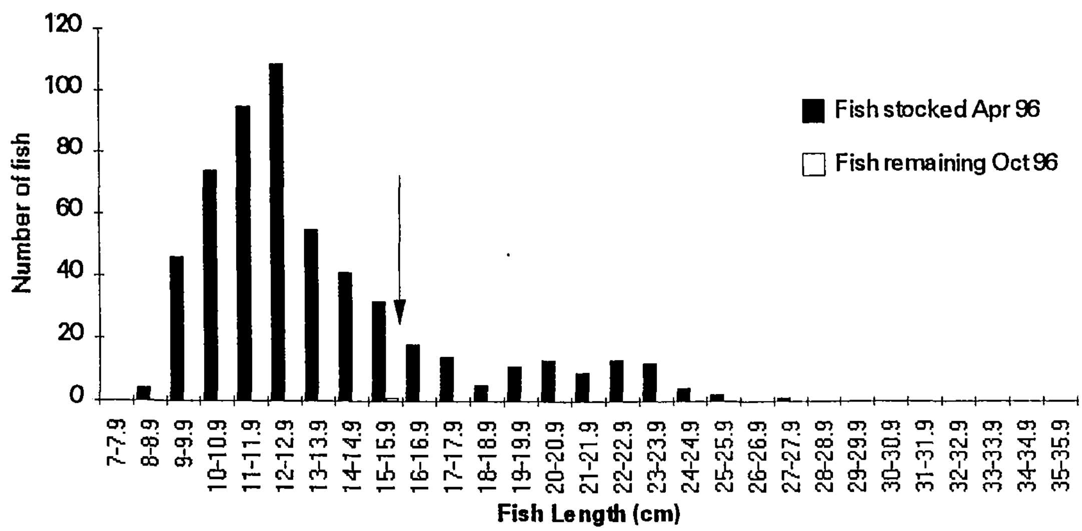
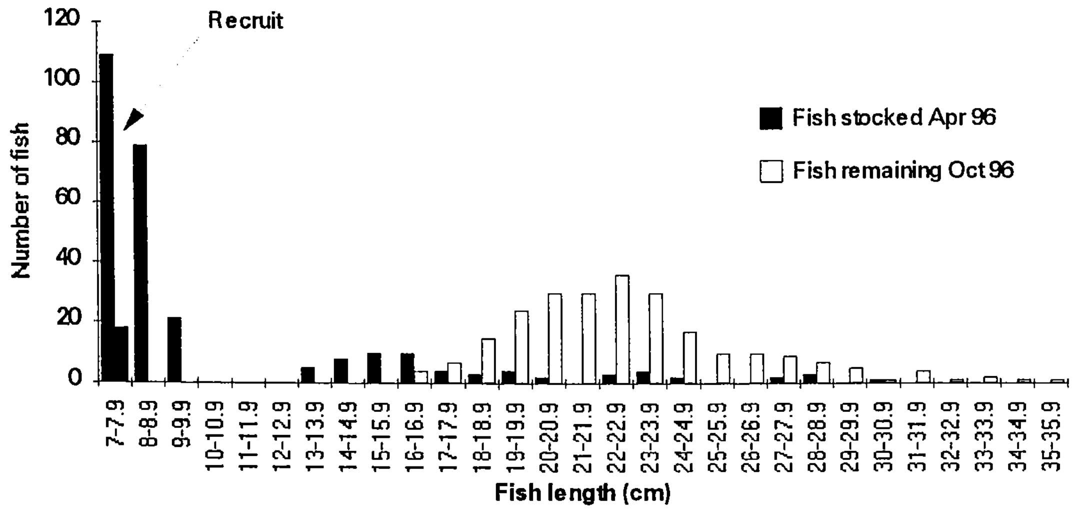


Figure 2.8. The numbers and sizes of roach *Rutilus rutilus* put into two lagoons mid-April 1996 and those present on draining the lagoons six month later in October 1996. Solid arrow highlights remaining small roach in test lagoon, dotted arrow new recruits.

<u>**Control lagoon**</u>



<u>**Test lagoon**</u>

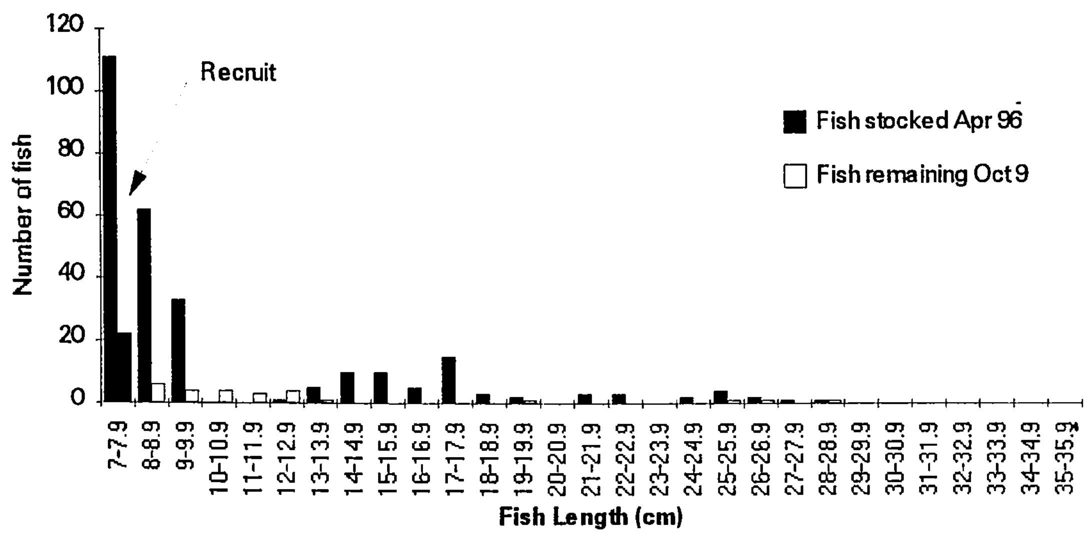


Figure 2.9. The numbers and sizes of carp *Cyprinus carpio* put into two lagoons mid-April 1996 and those present on draining the lagoons six month later in October 1996. Solid arrow highlights remaining small carp in test lagoon, dotted arrow new recruits.

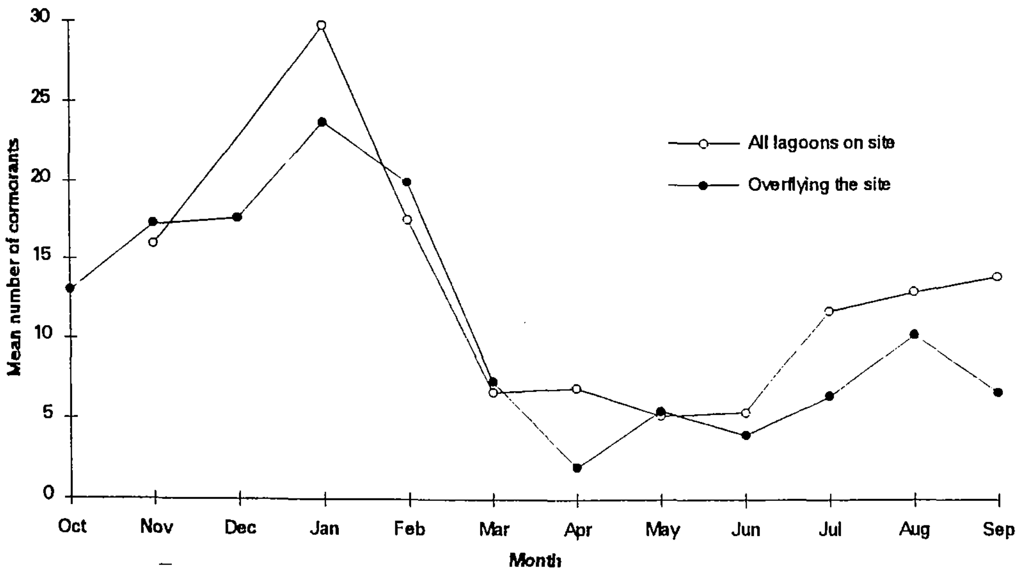


Figure 2.10. The mean number of cormorants recorded (i) on the whole Rye Meads site and (ii) overflying the test and control lagoons.

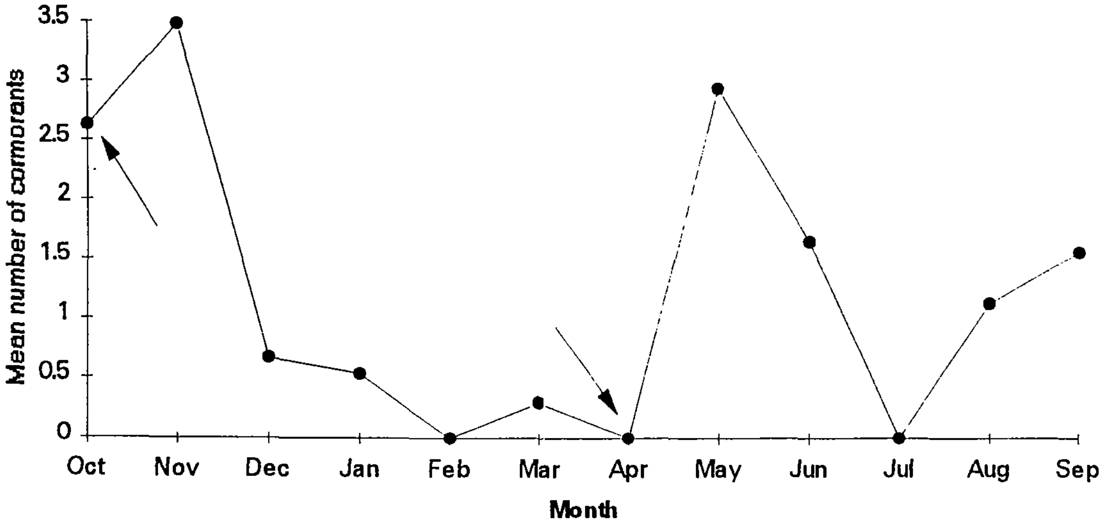


Figure 2.11. Monthly variation in the estimated mean number of cormorants using the test lagoon. Arrows indicate times of fish stocking.

(Figure 2.11). Numbers peaked again following the second stocking in April 1996 at 3.0 birds d^{-1} during May, before declining to 0.0 - 1.7 birds d^{-1} (Figure 2.11).

There are several points worthy of note. Peak winter occupancy of the test lagoon was a little higher than that of the summer period, but mean occupancy during the remainder of the winter was less than that during the remainder of the summer. Overall, however, the mean daily occupancy of the test lagoon by cormorants was similar for both periods (winter mean = 1.2 birds d^{-1}, summer mean = 1.1 birds d^{-1}) although clearly proportionately more local birds used the site during the summer compared to during the winter. This is perhaps surprising as the number of birds in the area was markedly higher during the winter period compared to the summer period (Figure 2.10). Expressing both the number of birds overflying the test lagoon and those actually using it as proportions per month clearly shows, however, the differences between the pattern of lagoon occupancy and the local abundance of birds (Figure 2.12). Indeed there was no correlation between the number of birds using the lagoon and those recorded overflying the site (r_{72} = 0.039, ns). There was, however, a strong correlation between the mean monthly counts of birds overflying the site and the mean monthly ringer counts of birds on the site as a whole (r_8 = 0.983, $p < 0.001$) suggesting that lagoon occupancy was to some extent independent of seasonal changes in the abundance of the local cormorant population.

Diurnal variation

Although most cormorants were observed overflying the test lagoons in the early morning and late afternoon, particularly during the winter period (Figure 2.13) they tended to use the test lagoon predominantly around midday and early morning in the winter and early morning during the summer.

2.2.3 Cormorant feeding behaviour

Winter period (October 1995 - April 1996)

During the 159 hours of observations in the winter period 18 individual cormorant feeding bouts were seen on the test lagoon. During these bouts a total of 243 dives were recorded (each lasting on average between 8 - 18 seconds) and five fish were caught. All fish caught were between 5 - 10 cm in length with the exception of one 23 cm carp that was dropped by a bird. Feeding success was therefore low with only 16.7% of feeding bouts resulting in at least one fish being caught, equivalent to just 2% of dives being successful. Feeding bouts were typically of short mean duration (5.8 ± 5.4 SD mins) and the mean dive rate was also low (2.2 dives min^{-1}) (Table 2.3).

Summer period (April 1996 - October 1996)

11 feeding bouts were seen during 144 hours of observations in the summer period. During these bouts 96 dives were recorded which resulted in the capture of seven fish, all 5 - 10 cm in length. The proportion of feeding bouts that were successful was, therefore, 54.6%, considerably greater than during the winter period and dive success was also greater (7.3% of dives successful). The lengths of feeding bouts (5.1 ± 3.9 SD mins) and mean dive rate (2.1 dives min^{-1}) was, however, similar to the winter period (Table 2.3).

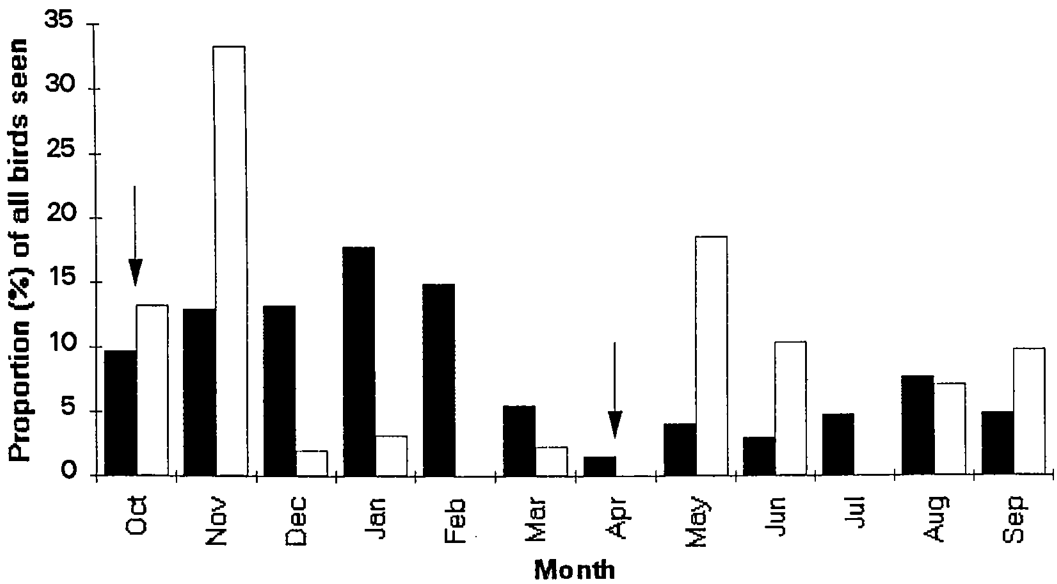
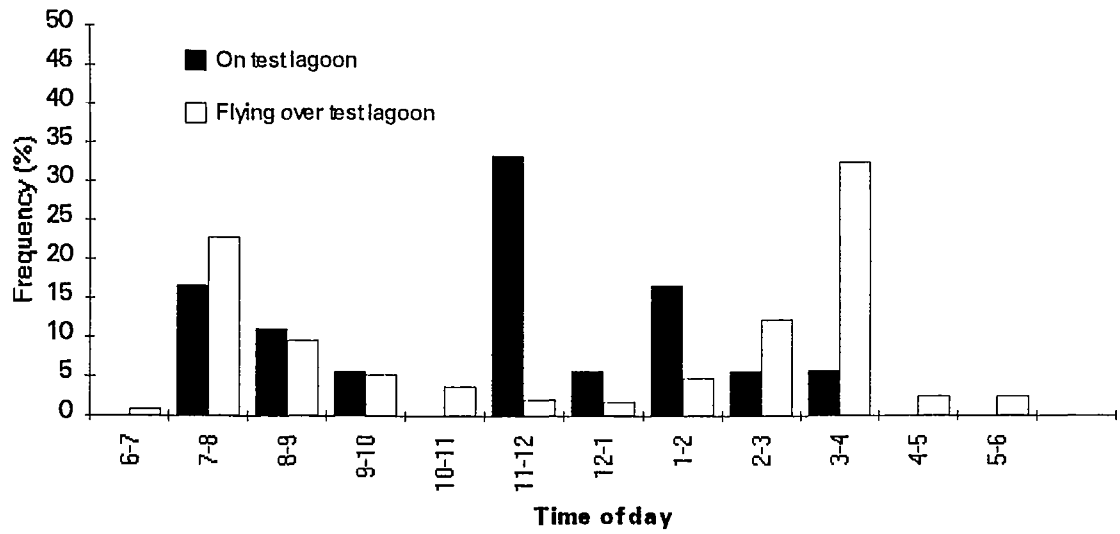


Figure 2.12. Monthly variation in the proportion of all birds seen (i) overflying the lagoons (black bars) and (ii) using the test lagoon (open bars). Arrows show when stocking took place.

Winter Period



Summer Period

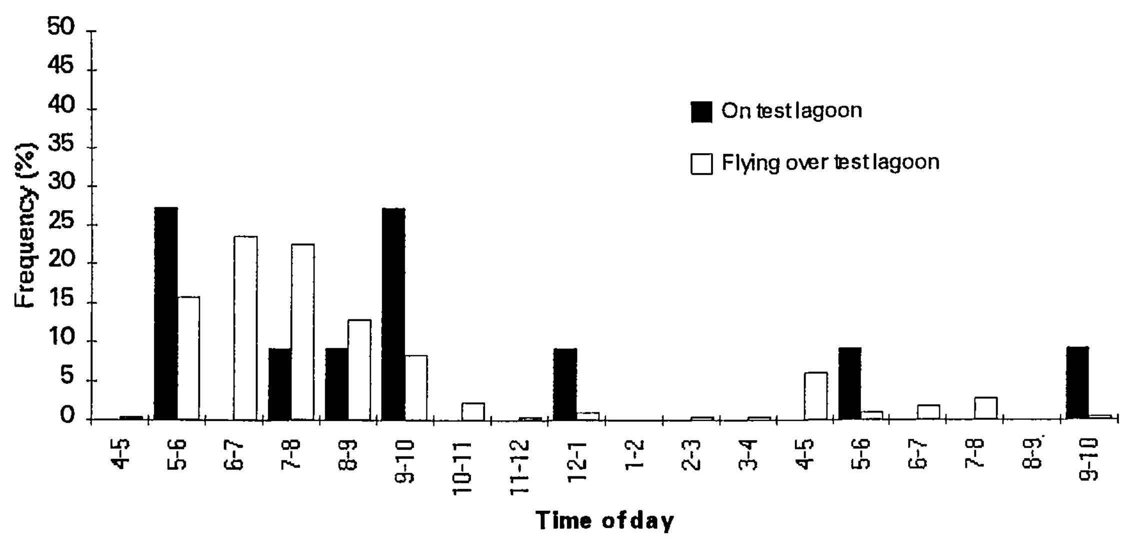


Figure 2.13 Diurnal variation in the numbers of cormorants at Rye Meads. Data are for the percentage frequency of (i) all birds overflying the Rye Meads lagoons and (ii) all birds using the test lagoon, as a function of time of day.

Table 2.3. Feeding behaviour of cormorants on the uncovered test lagoon at Rye Meads during the winter and summer periods. Data in parentheses are %.

	Winter Period	Summer Period
Hours of observations	152	144
Number of foraging bouts observed	18	11
Mean ± SD duration of foraging bouts (mins)	5.8 ± 5.4	5.1 ± 3.9
Number of successful foraging bouts observed	3 (16.7)	6 (54.6)
Total number of observed fish caught	5	7
Number of dives observed	243	96
Number of successful dives observed i.e. when a fish was caught	5 (2.0)	7 (7.3)
Mean number of dives min^{-1}	2.2	2.1
Range of dive durations (secs)	8.4 - 18.0	9.6 - 12.5

2.2.4 Cormorant impact

Drain down and netting of the control and test lagoons enabled the numbers of missing fish to be counted but did not provide any information on where these fish went. The proportion of these missing fish that may have been eaten by cormorants were estimated therefore, in a number of ways. Two methods were initially used (see below) to give an idea of the likely range of stock depredation by cormorants at the Rye Meads site. Each method, moreover, necessarily made certain assumptions. The robustness of estimates derived by each method are therefore likely to vary and the limitations of impact estimates so derived need to be carefully considered when interpreting the data presented in this report (see Sections 2.3 and 2.4).

Estimates based on the theoretical daily food requirements of cormorants.

During the whole study 1290 fish were unaccounted for in the test lagoon after 'natural' post-stocking mortality had been taken into account and survivors had been counted. In theory, therefore, cormorants could have eaten all 1290 fish, none of them, or some amount in between. Considering the birds' daily food intake is one way to estimate which of these possibilities is most realistic. If the average mass of each fish is assumed to be 45.3 g (from initial stocking data) this is equivalent to 58 437 g of fish that could have been removed by cormorants. Now, if the daily food requirement of a cormorant is assumed to be even as little as 300 g d^{-1} (Diet Assessment and Food Intake Working Group 1995), only 195 bird days at the site would have been required to remove all 1290 fish (i.e. 58 437 / 300). Over the 351 day study period as a whole, this equates to an occupancy of just 0.56 birds d^{-1} (i.e. 195 / 351). As the average occupancy of the site was almost twice this (Figure 2.11; Section 1.2.2(i)), estimates of impact based on occupancy data alone could easily account for the loss of the 1290 missing fish from the test lagoon. Put slightly differently, on the basis of even a modest daily food requirement the cormorant occupancy at the Rye Meads test lagoon could easily have been sufficient to explain the 54.9% reduction in stock not accounted for by 'natural' post-stocking mortality during the course of the 12 month study. This figure represents, therefore, the maximum theoretical possible impact at the site and is equivalent to approximately 1.5 x the average 36.8% 'natural' post-stocking mortality (Tables 2.1 and 2.2).

Estimates based on feeding observations at the site.

Data from feeding observations can also be used to derive an estimate of the number of fish likely to have been removed by cormorants. This method takes into account the birds' actual behaviour at the test lagoon (as opposed to the purely theoretical considerations above) by looking at the rates at which fish were caught by cormorants and eaten at the surface during field observations (Table 2.3). This estimate was derived as follows.

For every observation session the number of fish caught was recorded. For each of these sessions an hourly consumption rate (fish h^{-1}) was then calculated (as nearly all sessions tended to be four hours long this usually just entailed dividing the number of fish caught by four). This was then multiplied by the number of hours of daylight available for feeding on the day the session took place (i.e. dawn - dusk, from sunrise - sunset tables). This enabled one estimate of daily consumption (fish d^{-1}) to be calculated from the data collected during each observation session. As these rates were, however, likely to vary throughout the year, monthly averages were used in the final 'impact' calculation. In other words, suppose six observation sessions took place in a particular month, this would generate six daily consumption rates. The number of fish likely to have been consumed by cormorants during this month would be estimated, therefore, by taking the average of these six estimates and multiplying them by the number of days in that month. Such monthly figures were finally appropriately summed to provide respective estimates of total fish consumed at the test lagoon during the winter or summer period (Tables 2.4 and 2.5).

Winter cormorant depredation appeared to be confined to November as no fish were seen to be caught at any other time during the winter period despite the occasional presence of birds. Their low occupancy and poor success when using the site meant that on the basis of their observed catch rates they were only responsible for the removal of 44 (7.0%) of the unaccounted for 622 fish presumed lost to predators in the test lagoon. Expressed as a proportion of the original stock this is equivalent to only 3.7% or approximately a tenth of the natural (control) mortality (section 1.2.1).

In apparent contrast to the winter period, cormorants were observed not only to catch fish throughout the summer but were generally more successful during the latter (section 1.2.3). Indeed, estimates based on feeding observations showed that cormorants caught almost three times as many fish during the summer period compared to the equivalent winter period, although catches were still low. Despite this proportional increase in depredation only 16.9% of the 668 fish presumed lost to predators were attributable to these birds, equivalent to 9.7% of the original stock (Table 2.5) and again far less than that attributable to natural (control) mortality (Section 1.2.1).

2.3 Discussion

The two methods of estimating cormorant depredation at the Rye Meads lagoons shown above provide a range of values. Over the study year as a whole these represent a loss to cormorants of between 6.7% of the original stock (from estimates based on empirical feeding observation data) and 54.9% of the original stock (from estimates based on theoretical daily food intake data). In addition, however it was clear that what appeared to be substantial 'natural' post-stocking mortality occurred in the netted (control) lagoon that could not be attributed to predators. These points are discussed below.

2.3.1 Post-stocking mortality: are the levels reported at Rye Meads unusual?

Although 90 - 95% of fish were missing from the test lagoon at drain down, more than a third of these fish appeared to have died shortly after stocking, not as a result of cormorants or other predators but probably as a result of handling stress. Without the control (netted) lagoon this would not have been detected and it is easy to see why the loss of fish from a fishery is often entirely blamed on predators. If high post-stocking mortality is commonplace, however, the perceived reduction in angling catches at some stocked fisheries may have less to do with predators than has been previously thought. Some Dutch studies suggest this may indeed be the case and that the post-stocking mortalities found at Rye Meads (effectively a stock pond) are (i) actually much lower than is often the case in stock ponds and (ii) that post-stocking mortality in typical closed sport fisheries can also be alarmingly high.

Table 2.4. Cormorant depredation of fish in the test lagoon during the winter period.

	Mean no. fish caught per hour	Mean no. fish caught per day	No. days included in winter period	Mean no. fish caught per month
October	0	0	18	0
November	0.16	1.45	30	43.5
December	0	0	31	0
January	0	0	31	0
February	0	0	29	0
March	0	0	31	0
April	0	0	10	0
TOTAL for winter period (to the nearest fish)	-	-	-	44
Proportion (%) of fish unaccounted for in treament lagoon (excluding [1]control mortality)	-	-	-	6.6%
Proportion (%) of original stock (n = 1184 fish)	-	-	-	3.7%

[1] See section 1.2.1

Table 2.5. Cormorant depredation of fish in the test lagoon during the summer period.

	Mean no. fish caught per hour	Mean no. fish caught per day	No. days included in winter period	Mean no. fish caught per month
April	0.00	0.0	14	0
May	0.06	1.0	31	31.0
Jun	0.04	0.7	30	21.0
July	0.00	0.0	31	0
August	0.08	1.2	31	37.2
September	0.06	0.8	30	24.0
October	0.00	0.0	5	0
TOTAL for summer period (to nearest fish)	-	-	-	113
Proportion (%) of fish unaccounted for in treament lagoon (excluding [1]control mortality)	-	-	-	16.9%
Proportion (%) of original stock (n = 1165 fish)	-	-	-	9.7%

[1] See section 1.2.1

From 1972 to 1980 experiments were carried out in drainable ponds in the Netherlands to quantify the survival of stocked roach (Riemens 1985, Riemens 1984). Roach of between 15 - 30 cm were seine netted and transported to holding tanks just prior to stocking. Fish were stocked between November 1st and March 31st in enclosed 0.05 - 1.0 ha, shallow (1 m), rectangular experimental ponds at a density of 150 kg ha^{-1}. the ponds were drained in July of the same year and survival calculated as the percentage of living fish relative to the total numbers stocked into the ponds. The similarities of the above with the currently reported Rye Meads experiment is worthy of note.

The results of this seven year study showed the **survival** of roach after three to four months ranged from 0.8 - 67.3% with an average of just 23.0%. In other words stocked roach typically experienced a **post-stocking mortality** during this time of 77.0%, more than twice the average for all species found in the current study. At Rye Meads the post-stocking mortality of roach alone was 41.9% and 50.5% during the winter and summer periods, respectively (Tables 2.1 and 2.2), substantially less than that found in the Dutch study. The experiments mentioned above were, however, carried out in stock ponds without predators and whilst this is clearly comparable to the control lagoon at Rye Meads study, one should ask, are such post-stocking mortalities representative of those in angled waters?

To answer this question Riemens (1985) carried out field experiments. Roach were again used and stocked this time in three small (1 - 3 ha) fisheries in different parts of the Netherlands. The fish were pan-jetted and stocked at a density of 150 kg ha^{-1} in March. Simultaneously three experimental ponds of comparable size were stocked at similar levels and acted as controls. Survival was determined at two of the field sites in June (one by a Petersen estimation after seine netting and the other by draining) and the other field site in October (again by seine netting). The experimental (control) ponds were drained at the same time as their field 'partners' were sampled.

The **mortality** at the sites were as follows (numbers in parentheses refer to the corresponding stock pond [control] mortality for each field site); (i) field site at Kampen 68.7% (control 36.0%); (ii) field site at Valkenswaard 77.7% (control 55.2%) and (iii) field site at Westerhoven 44.5% (control 40.4%). In each case the mortality at the sport fishery was greater than in the control ponds. This could be explained by the presence of predators and illegal fishing at two of the sites (Kampen and Valkenswaard) but not at the third site, Westerhoven, where no predators were present and no illegal fish removal occurred during the experiment. The latter site is especially noteworthy as this fishery was also drainable and so provided perhaps the most accurate estimate of mortality of the three field sites. On the basis of these data, Riemens concluded that 'the survival of roach, stocked in closed sport-fishery waters, is not better than in the experimental ponds' (Riemens 1985, pg 171).

The above studies are important for a number of reasons. First they show that the level of post-stocking mortality recorded at Rye Meads is not unusual and may in fact be relatively low. Second, they show that post-stocking mortality in closed sport fisheries may be at least as high as those experienced at stock ponds. Third, they identify the main cause of this mortality to be stress induced, predominantly by storage during grading and stock accumulation and less so the netting and transportation of fish. Four, they show that in many instances more than three quarters of stocked roach may have died before a single angler gets a chance to catch one and that this has nothing to do with cormorants or any other predator.

2.3.2 Impact estimates: some theoretical and empirical considerations

Within two weeks of stocking in both October and April cormorants began to visit the test lagoons after which there was a clear peak in occupancy that occurred about 30 - 40 days post-stocking and a decline thereafter. Nonetheless, over the study as a whole, occupancy was low but at a level that could still, theoretically, have easily accounted for the fish missing from the test lagoon. Estimates based on occupancy and daily food intake depend critically, however, on the assumption that each cormorant visiting the lagoon meets its full daily food requirement there. For this to be true, at the level of occupancy observed each bird would need to have taken approximately 3.7 fish d^{-1}, or, on average 0.3 fish hr^{-1} to cause the observed 'impact'. Only 12 fish were seen to be caught by cormorants in 296 hours of observations, however, equivalent to a catch rate of just 0.04 fish hr^{-1}, or a little over 10% of what would be required to account for the missing fish in the test lagoon. If these data are accurate they show that impact estimates based on theoretical food intake data would grossly overestimate the damage caused by cormorants at Rye Meads.

Looking at the feeding success and catch rates of cormorants in other studies is one way to see how typical the behaviour of cormorants was at Rye Meads and whether the impact estimates based on feeding observations is likely to be realistic. Data from four still water sites in the north-west and midlands have shown that the proportion of successful feeding bouts by cormorants can vary between 12-80% and dive success can vary between 2-15% (Davies 1997, Cowx *et al.* 1996). At Rye Meads during the winter, feeding success was near the bottom of these ranges (16.7% and 2.0% respectively, Table 1.4) and during the summer approximately mid-way (54.6% and 7.3% respectively, Table 1.4). Both dive rates (mean = 2.1 dives min^{-1}) and catch rates (mean = 0.03 fish min^{-1}) at Rye Meads were also towards the lower end of the ranges quoted elsewhere (dive rates = 2.5 - 6.5 dives min^{-1}; catch rates = 0.00 - 1.14 fish min^{-1})(Davies 1997, Cowx *et al.* 1996). This relatively poor overall feeding success coupled with the low levels of occupancy at the site, suggests that cormorants might indeed be responsible for only approximately 7% of stock losses as suggested by feeding observations. This presents somewhat of an enigma because taking into account both natural (control) mortality and cormorant depredation still leaves 578 fish (48.8%) of the original winter stock and 555 fish (47.6%) of the original summer stock unaccounted for. Assuming the estimates based on feeding observations to be reasonable where might these fish have gone?

2.3.3 Was some cormorant depredation missed?

One explanation could be that cormorants took fish that the observers missed. Cormorants are diurnal opportunist feeders. They fly to communal night roosts at dusk where they remain until first light before flying out to feeding areas (Cowx *et al.*, 1996, Davies and Feltham 1996, Davies and Feltham 1995, Feare 1988, van Dobben 1952). As observations at the test lagoons began up to half an hour before sunrise and finished up to half an hour after sunset it does not seem possible that birds using the lagoon either very early or very late in the day could have been missed. Estimates of cormorant occupancy were unlikely, therefore, to have been compromised by inadequate sampling. Indeed the only circumstances under which observers could have under-recorded the number of fish being eaten by cormorants using the site was if birds swallowed fish underwater.

During the 159 hours of observations in the winter period 243 dives were recorded, equivalent to an average of 1.5 dives h^{-1}. As the winter period comprised 1758 hours of daylight this would have resulted in an estimated 2637 dives at the site. It has already been shown (Table 2.4) that the rates of prey capture during the winter appeared to be so low that they would have resulted in only 44 fish being caught. If the 44 dives needed to catch these fish are subtracted from the 2637 estimated to have taken place, this still leaves 2593 dives during which birds apparently did not catch any fish, plus 578 fish (622 - 44) still unaccounted for. Could these fish have been swallowed underwater? For this to be true 22% of dives (about 1 in 5) during the winter would need to have resulted in a fish being consumed underwater and hence undetected by the observers, or put another way each cormorant visiting the site would need to have eaten 13 fish undetected underwater for every one consumed at the surface.

During the 144 hours of observations in the summer period 96 dives were recorded, equivalent to an average of 0.7 dives h^{-1}. As the summer period comprised 2514 hours of daylight this would have resulted in an estimated 1173 dives at the site. Based on feeding observations 113 fish were caught, leaving 1060 dives (1173 - 113) during which birds apparently did not catch any fish, plus 555 fish (668 - 113) still unaccounted for. During this period then 52% of the observed dives would need to have resulted in fish being swallowed under water to account for the fish missing from the test lagoon, equivalent to five fish consumed below the surface for each one consumed at the surface.

Whilst cormorants may be capable of swallowing fish under water (especially perhaps small ones) the likelihood of this being a serious source of fish mortality at Rye Meads would appear quite limited for several reasons.

First, although a few anecdotal reports of cormorants swallowing fish underwater exist, published scientific data supporting this view is sparse and apparently restricted to a relative of the cormorant, the shag (*P. aristotelis*) feeding in marine environments. For example, Wanless *et al.* (1993) demonstrated that shags sometimes swallowed up to seven sandeels (*Ammodytes* sp.) underwater but these birds were feeding in relatively deep water off the coast. Observations of *P. carbo* at many fresh water sites conversely have demonstrated that, particularly in shallow water (<3 m i.e similar to the Rye Meads test lagoon), fish of all sizes (including cyprinid fry) are regularly brought to the surface to be swallowed (see e.g. Davies 1997, Cowx *et al.* 1996).

Second, dive times at the test lagoon were short (typically < 18 seconds) presumably due to the shallow depth in which the birds were feeding, so that the opportunity to catch and subdue multiple prey items under water in a similar way to Shags is severely limited.

Third, if cormorants regularly swallow large numbers of fish underwater one would expect there to be poor agreement between feeding observation data and stomach content data. Studies of cormorants feeding inland at some freshwater sites have shown, however, excellent agreement between the numbers of fish seen to be consumed at the surface compared to what was recovered from the stomachs of the same birds shot later (e.g. Davies 1997, Holden, pers.comm.).

Fourth, with the exception of one large carp (and that got away) all the fish seen to be taken by cormorants at the test lagoon were small (5 - 10 cm) and yet fish of up to 30 cm were stocked (Figs. 2.1 - 2.3). It seems most unlikely that birds would bring small fish to the surface to eat but swallow the large ones under water. The situation is made still more unlikely because it was the small stocked fish that tended to suffer proportionately greater natural post-stocking mortality than the large fish resulting in size distributions biased towards the larger size classes, especially during the summer when substantial growth also occurred (Figs. 2.4 - 2.9).

2.3.4 Was some depredation was caused by other predators?

Several species that include fish in their diets were recorded during observations of the test lagoon in addition to cormorants. These were; kingfisher *Alcedo atthis*, little grebe *Tachybaptus ruficollis* and grey heron *Ardea cinerea*. An otter *Lutra lutra* was also known to be in the locality but was never seen and no spraints or tracks were ever found around the test lagoon. A kingfisher was recorded on four visits to the lagoon during October and November and a little grebe once in December and on four of the five visits in June. It is doubtful whether either could have caught even the smallest stocked fish and that any depredation, if it occurred, was restricted to newly recruited fry during the summer. The impact of kingfishers and little grebes on the stocked fish was likely, therefore, to have been negligible. This may not, however, have been the case for herons.

Herons were the only other birds known to have caught fish at the lagoon. Indeed, the first record of any piscivore using the lagoon after the first stocking in October was that of a heron catching a fish eight days post-stocking. In total, herons were recorded on three of the winter visits to the test lagoon and during ten summer visits when they were present almost as often as cormorants. Herons were only recorded at the site around dusk and dawn, particularly the latter and on about 60% of occasions they were already present at the lagoon and were scared off by the arrival of the observers. Unlike cormorants, herons are known to regularly feed at night, even during the winter. In a Belgian study, for example, Draulans and van Vessem (1985) found that between November and February adult grey herons were located at fish ponds and fish farms mostly at night and least during day-light, whilst first year birds showed no differences in the times at which they fed. Carss (1993) observed herons at fish farms in Argyll, western Scotland during both the winter and the summer. He found that herons regularly took fish throughout the hours of darkness and that most birds visited the site almost exclusively at night. In both studies human disturbance during the hours of day-light tended to result in herons leaving the site.

At Rye Meads some depredation of fish stocks in the test lagoon could have taken place by herons at night. This would have gone undetected because no night-time observations were carried out as part of the research. On the basis of known heron energetic food requirements (300 g d^{-1}; Meyer 1982, Cramp and Simmons 1977) one heron meeting it's daily requirement on alternate nights would be sufficient to account for all the missing fish

2.4 Conclusions and Recommendations

Three main conclusions can be drawn from the study. First, post-stocking mortality in cyprinids, particularly small roach and bream, far from being negligible as is commonly perceived, can be similar to, if not greater than, that caused by predators. Indeed the 37% post-stocking mortality recorded in the present study is actually low compared to some studies (Riemens 1985, Riemens 1984). There is, moreover, no evidence to suggest that fish stocked in natural lakes and ponds survive any better than those in stock ponds (Riemens 1985, Riemens 1984). Second, only a small proportion (6.7%) of the loss of the original Rye Meads stock could, on the basis of the data collected, be **clearly** attributed to cormorants. Third, the majority of fish lost from the test lagoon (> 48%) could not be attributed with confidence to any specific predator and, moreover, exceeded the combined mortality due to post-stocking and known consumption by cormorants. Two alternative hypotheses were, therefore, proposed to try to account for these unknown losses. They may be summarized as follows;

Hypothesis 1. ALL fish unaccounted for by day-time observations of cormorants were swallowed underwater by these birds. If this was the case 54.9% of fish mortality would be attributable to cormorants and 36.8% to 'natural' post-stocking mortality. 8.3% of fish were survivors.

Hypothesis 2. ALL fish unaccounted for by day-time observations of cormorants were taken at night by herons. If this was the case 6.7% of fish mortality would be attributable to cormorants, 48.2% to herons and 36.8% to 'natural' post-stocking mortality. 8.3% of fish were survivors.

Unfortunately, neither the extent (if any) to which cormorants swallowed fish underwater (Hypothesis 1) nor the degree (if any) of nocturnal depredation by herons (Hypothesis 2) at Rye Meads could be tested with the data collected. Nocturnal depredation by herons at freshwater fisheries is, however, well documented in the literature (Draulans and van Vessem 1985, Carss 1993) whereas the underwater consumption of fish by cormorants is not and appears instead to be limited to related species feeding in marine environments (Wanless *et al.* 1987). On the basis of the literature it would seem that herons are potentially far more likely to be responsible for the additional depredation at Rye Meads, than are cormorants, but this remains speculative. Should an experiment of the kind reported here be repeated this could, however, be easily tested by either (i) carrying out night time observations at the site or (ii) placing wires around the margins of the test lagoon to dissuade herons from using the site whilst not disturbing cormorants. Both of these approaches would enable a future study to more confidently distinguish the potential roles of cormorants, herons and any other predators in causing the mortality of fish stocked at the site.

The Rye Meads study highlights the difficulties in estimating the impact of cormorants on freshwater fish populations, even under carefully designed experimental conditions. The uncertainty regarding the major source of mortality at the site should be particularly noted. This is especially important because different interpretations placed on such impact data can lead to very different decisions about how best to deal with perceived predator problems at a fishery. For example, if nocturnal depredation by herons (or other predators) is significant at stocked ponds, shooting cormorants that use the site during the day will do little to protect fish stocks. Conversely if cormorants swallow large numbers of fish underwater, protecting the site from herons will also do little to protect fish stocks. In either case, moreover, it is clear that 'natural' post-stocking mortality of species such as roach and bream should also be taken into account and serious consideration given to whether stocking these species at a particular fishery is appropriate. Put simply, if levels of post-stocking mortality can be as great as some studies suggests, then protecting such a fishery from cormorants and/or herons by whatever means could simply reduce losses to an already heavily impoverished stock rather than maintaining the original stock. Reduced handling and particularly reduced storage times of fish prior to and during stocking could, therefore, be at least as effective in maintaining fish stocks as protecting fish from potential depredation by birds.

3.0 A QUESTIONNAIRE SURVEY OF THE PERCEIVED IMPACT OF CORMORANTS ON THE FISH STOCKS OF STILLWATERS IN THE LEA AND COLNE VALLEYS.

3.1 Methods

A questionnaire survey of the perceived impact of cormorants on the fish stocks of stillwaters in the Lea and Colne Valleys (Figure 1.3) was carried out during 1996 to compliment the experimental work at the Rye Meads test lagoons. Three copies of the questionnaire were sent to each of approximately 350 angling clubs / fisheries owners. The questionnaire comprised two main sections.

(i) Section 1.

Angling clubs / fishery owners were asked to supply;

(a) **details of their stillwater(s)** (up to five could be specified on the questionnaire) including the name of each stillwater, it's area and NGR,

(b) an estimate of **cormorant presence** at each stillwater (using the specified categories shown) including;

(i) the *typical numbers* of birds present per day: 0, 1-4, 5-10, 11-15, 15-20, 21-30, 31-50, 50+ birds,

(ii) the *time(s) of day* these birds usually visited the site: dawn - 10am, 10am - 2pm, 2pm - dusk

(iii) the *season(s)* during which birds were usually present: Dec - Feb, Mar - May, Jun - Aug, Sep - Nov,

(c) information on **perceived fish depredation** at each stillwater including;

(i) the observed *number of fish taken* per visit per bird

(ii) the main *fish species taken*

(iii) the *size(s) of fish taken*

(ii) Section 2

This section comprised nine questions designed to assess to what extent, if any, angling catches had changed in recent years and, if so, why. For each of the stillwater(s) specified in Section 1 angling clubs / fishery owners were asked to supply;

(a) information on any changes in the **sizes of fish caught** by pleasure and/or match anglers: decrease, no change, increase

(b) information on any changes in the **numbers of fish caught** by pleasure and/or match anglers: decrease, no change, increase

(c) information on any changes in the **species of fish caught** by pleasure and/or match anglers: from spp. A, B, C etc. to D, E, F etc.

(d) details of **fish stocked**; species, numbers, size, dates, frequency

(e) information on the availability of historic **match weight data**: yes, no

(f) information on when **cormorants** were first noticed at the site: this year, 1 year ago, 2 - 3 yrs ago, 3 - 5 yrs ago, 5+ years ago.

In addition, respondents were asked about their willingness for the information they provided to be used as part of an Environment Agency report with national circulation and were given the opportunity to add additional comments.

3.2 Results

101 completed questionnaires (8.4% of those sent) were available for analysis. Of these, 14 referred to river or stillwaters outside the Lea and Colne Valleys and so were excluded from subsequent analyses. The remaining 87 replies contained 141 records from 110 stillwater sites equivalent to about 25% of the 400+ angled waters in the region. The majority of sites have reportedly had cormorants visiting them for some years (Figure 3.1). Nearly three quarters of sites appeared to have had cormorants on them for > 3 years and relatively few respondents reported that birds had only recently begun to use their site (Figure 3.1).

3.2.1 Numbers of cormorants in relation to water body size.

The vast majority (78%) of water bodies in the survey had an area of ≤ 5 ha (Figure 3.2) and less than 5% had an area of more than 25 ha. Although the survey data were clearly heavily biased in favour of the small water bodies that dominate the study area, there was a significant positive correlation between median bird abundance score and rank water body size ($r_7 = 0.813$, $p < 0.05$, Figure 3.3). This general trend, however, hid a large amount of variation in the reported abundance of birds at the majority of sites. For example, the median abundance score recorded at all stillwaters ≤ 5 ha in size (n = 110) was one, equivalent to these sites being visited typically by 1 - 4 birds (Figure 3.4) and yet records ranged from no birds at all to more than 50.

3.2.2 Seasonal variation in stillwater occupancy.

Of the 141 records, 19 reported that no cormorants were present and a further five records did not provide data on temporal variation in cormorant occupancy. Data on

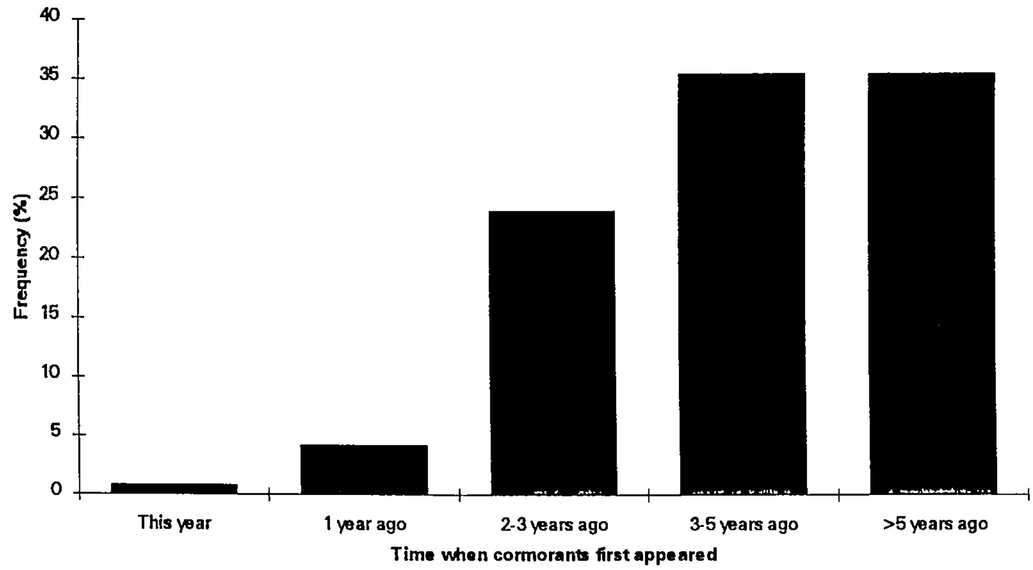


Figure 3.1 History of cormorant occupancy at still waters in the Lea and Colne valleys. N = 141 records from 110 sites.

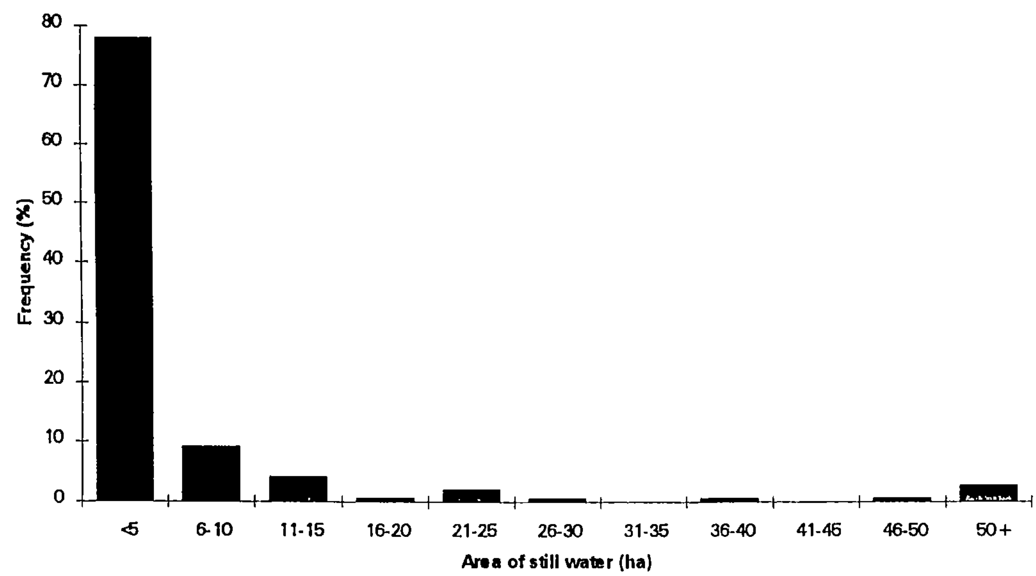


Figure 3.2 Frequency (%) of 110 still waters in the Lea and Colne valleys in relation to their size (ha).

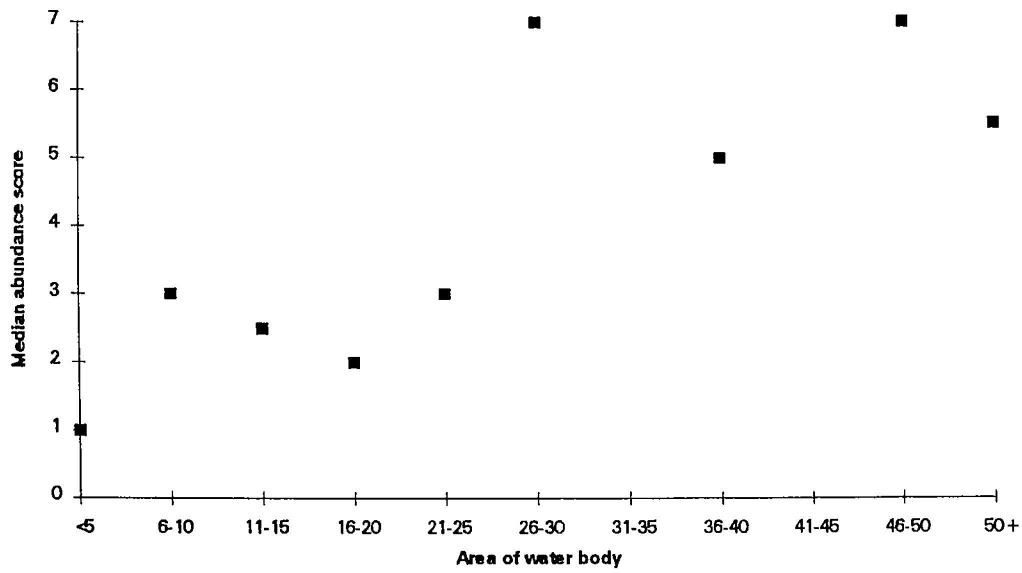


Figure 3.3 Median cormorant abundance score in relation to water body size in the Lea and Colne valleys. Abundance scores 0-7 are equivalent to; 0, 1-4, 5-10, 11-15, 16-20, 21-30, 31-50 and 50+ birds, respectively. Data are from 141 still water records.

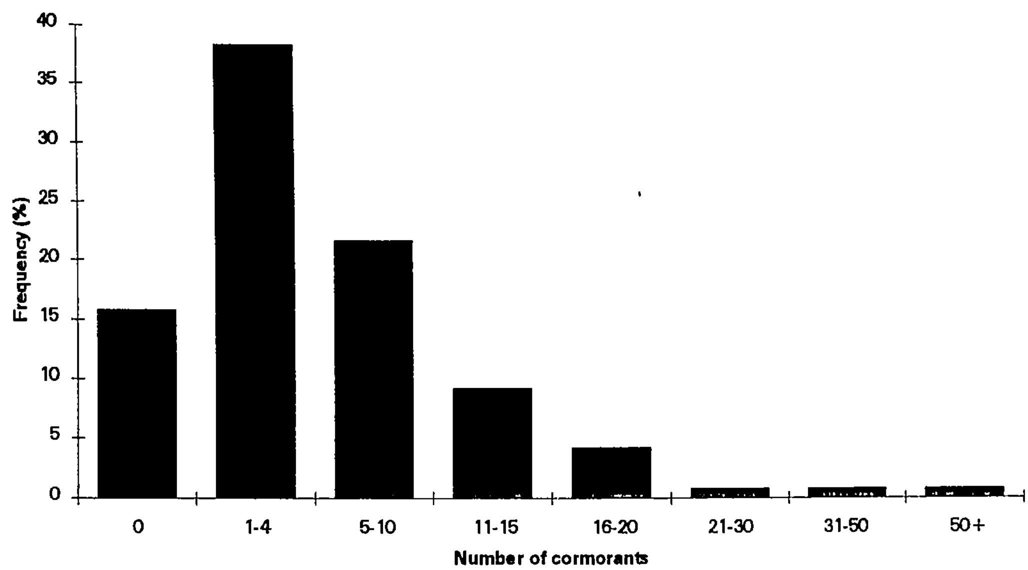


Figure 3.4 Reported abundance of cormorants at small still waters (≤ 5 ha) in the Lea and Colne valleys. N = 110 records.

seasonal variation in stillwater occupancy were available, therefore, from 117 records only. The perceived occupancy of stillwater sites by cormorants showed a clear seasonal trend. The majority of respondents (68.4%) reported that cormorants were present at their waters during the winter (December - February) each year with the least number of respondents (23.9%) reporting birds during the summer (June - August)(Figure 3.5). Almost a quarter of respondents reported that cormorants were at their waters exclusively during the winter months, 9.4% reported exclusive occupancy during the autumn, another 9.4% occupancy during the spring only and 5.1% reported birds were only present during the summer (Table 3.1). 16.2% of waters claimed to have cormorants year round and other 17.1% claimed to have cormorants all year except during the summer (Table 3.1).

3.2.3 Diurnal variation in stillwater occupancy

Data were available from 117 records. In general, occupancy was reported to be greatest between dawn - 10am (83.8% of respondents) but birds were present at many sites during other parts of the day (Figure 3.6). A little under half of all respondents (46.5%) reported cormorants were present exclusively during the early morning period (dawn -10am), a further 10.5% reported cormorants were present both during early morning and later in the day (2pm - dusk), whilst almost a quarter of respondents (23.7%) reported all day occupancy by cormorants. A few stillwaters (7.9%) reported a cormorant presence only around midday.

3.2.4 The numbers of fish taken by cormorants

All respondents with cormorants at their sites completed this part of the questionnaire and so these analyses were based on 122 records. Almost half the respondents (48.4%) were unable to specify the numbers of fish typically consumed by cormorants during each visit to their stillwater. Of the remainder 15.5% stated that cormorants typically ate 1 - 2 fish per visit, 16.4% stated 3 - 4 fish and 16.4% stated 4+ fish (Figure 3.7). Interestingly, 3.3% of respondents reported that although cormorants were present at their sites they were not observed taking fish.

3.2.5 The species of fish taken by cormorants

Analyses were based on 103 records which commented on the species of fish taken by cormorants. The majority of respondents (77.7%) identified the species of fish eaten by cormorants at their stillwaters, but almost a quarter (22.3%) stated that they were unable to do so. Roach were the most often reported species taken by these birds (59.2% of records) followed by bream (32.0%), rudd (18.5%) and carp (14.6%)(Figure 3.8). Perch and trout were reported as prey in 9.7% or records respectively. Dace, crucians, tench, chub and eel were reported only infrequently.

3.2.6 The sizes of fish taken by cormorants

The most commonly reported overall average size range of fish taken by cormorants from the stillwaters of the Lea and Colne valleys was 10 - 20 cm (75% of 93 records). There was, however, some variation in the sizes of fish taken by birds with respect to species (Figure 3.9). Roach, rudd and bream showed similar patterns with the most commonly reported size taken being middle (10 - 20 cm) size range fish. Small (< 10 cm) and middle

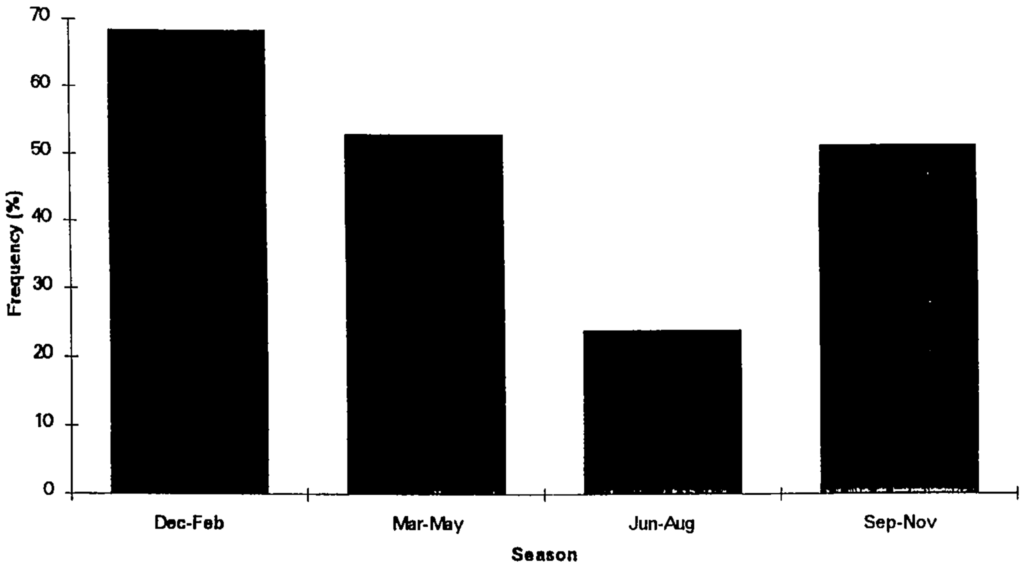


Figure 3.5 Pattern of cormorant occupancy at still waters in the Lea and Colne Valleys as a function of season. Data refer to the % of respondents reporting cormorants present during each season. N = 117 records.

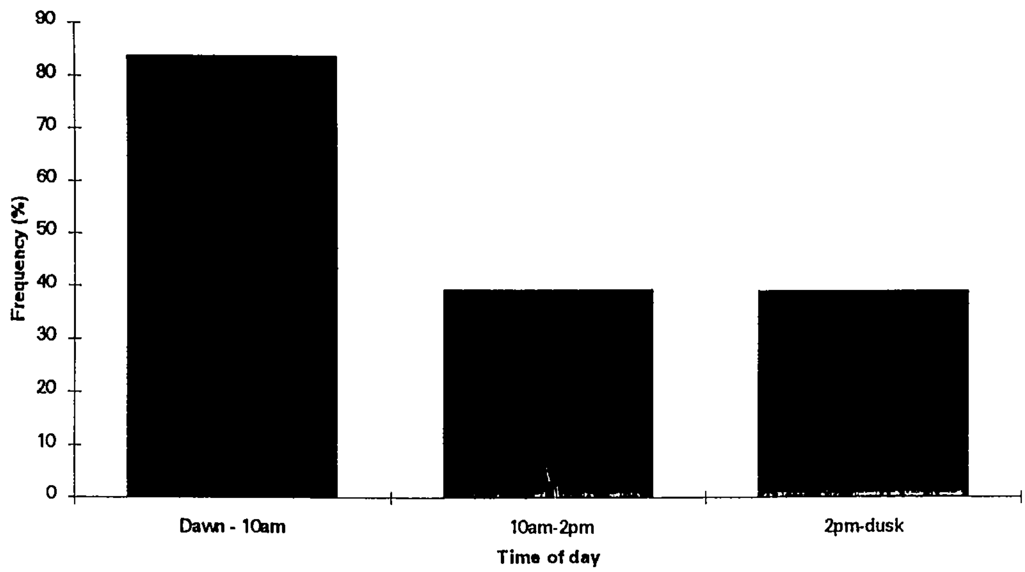


Figure 3.6 Diurnal pattern of cormorant occupancy at still waters in the Lea and Colne Valleys. Data refer to the % of respondents reporting cormorants present during each time period. N = 117 records.

Table 3.1 Details of the seasonal variation in the perceived occupancy of stillwater sites in the Lea and Colne valleys by cormorants. N = 117 records.

Season birds present	Number of sites	Proportion (%)
Winter (Dec-Feb) only	29	24.8
Spring (Mar-May) only	11	9.4
Summer (Jun-Aug) only	6	5.1
Autumn (Sep-Nov) only	11	9.4
All year	19	16.2
All year (except summer)	20	17.1
Spring and Summer	1	0.9
Summer and Autumn	2	1.7
Autumn and Winter	4	3.4
Winter and Spring	7	6.0
Other	7	6.0

size range perch were, however, reportedly taken with similar frequency but proportionately more trout and carp in the large (20+ cm) size range were reported to be taken.

3.2.7 Recent changes in the numbers of fish caught by anglers

131 records contained data on the reported changes in the numbers of fish caught by pleasure anglers over the last 2 - 3 years and 104 contained similar data for match anglers. Few records reported no changes (6.7-13.0%, Table 3.2) with the vast majority of records reporting a reduction in the numbers of fish being caught both by pleasure anglers (81.7% of records) and match anglers (89.4%). Only 3.8 - 5.3% of records reported that the numbers of fish being caught had increased and these records specified this was a direct result of stocking. Of 106 respondents who stated whether or not they had historical match records, 38.7% did and 61.3% did not. A further 37 respondents did not answer this question.

3.2.8 Recent changes in the sizes of fish caught by anglers

121 records contained data on the reported changes in the sizes of fish caught by pleasure anglers over the last 2 - 3 years and 91 contained similar data for match anglers. There were significant differences with respect to these changes between pleasure and match anglers ($\chi^2_2 = 10.57$, $p < 0.01$, Table 3.3). First, 19.8% of records stated there had been no change in the sizes of fish caught by pleasure anglers compared to only 7.7% for match anglers. Second, the proportion of records that showed pleasure anglers were catching larger (42.2%) or smaller fish (38.0%) than 2 - 3 years ago were similar, whilst the proportion of records that showed match anglers were catching larger fish (62.6%) was almost twice that of those catching smaller fish (29.7%)(Table 3.3).

3.2.9 Recent changes in the species of fish caught by anglers

Respondents were asked to provide information on any changes that had taken place over the last 2 - 3 years with respect to the main species of fish caught by pleasure and/or match anglers. They were asked specifically to state changes in the following way, for example, FROM bream TO roach i.e. what species **used** to be most often caught by anglers, (past catches) and what species were **now** most often caught by anglers (present catches). In addition respondents were asked if there had been any significant stocking during this time and if so the species, sizes and numbers of fish stocked and the stocking frequency.

Changes in the species of fish caught by match and pleasure anglers were similar (Figures 3.10 and 3.12). These data indicated that roach and bream **used** to be the most commonly reported main species caught by anglers, followed by perch, rudd, tench and carp, crucians and last of all trout. The most commonly reported species **in present catches** were, however, large carp and tench, followed by large bream and perch. In short, there has been a perceived shift in the species caught in recent years **from** roach, small-medium sized bream, perch and rudd **to** carp (particularly large ones), tench and large bream. Few stillwaters reported that roach, rudd or crucians were the main species now caught by anglers (Figures 3.10 and 3.12). Part of the reason for these changes may be the species

Table 3.2 Changes in the reported numbers of fish being caught by anglers over the last 2-3 years from stillwaters in the Lea and Colne valleys. N = no. records. % in parentheses.

	Less fish being caught	No change	More fish being caught	Total number of records
Pleasure anglers	107 (81.7)	17 (13.0)	7 (5.3)	131
Match anglers	93 (89.4)	7 (6.7)	4 (3.8)	104

Table 3.3 Changes in the reported sizes of fish being caught by anglers over the last 2-3 years from stillwaters in the Lea and Colne valleys. N = no. records. % in parentheses.

	Smaller fish being caught	No change	Larger fish being caught	Total number of records
Pleasure anglers	46 (38.0)	24 (19.8)	51 (42.2)	121
Match anglers	27 (29.7)	7 (7.7)	57 (62.6)	93

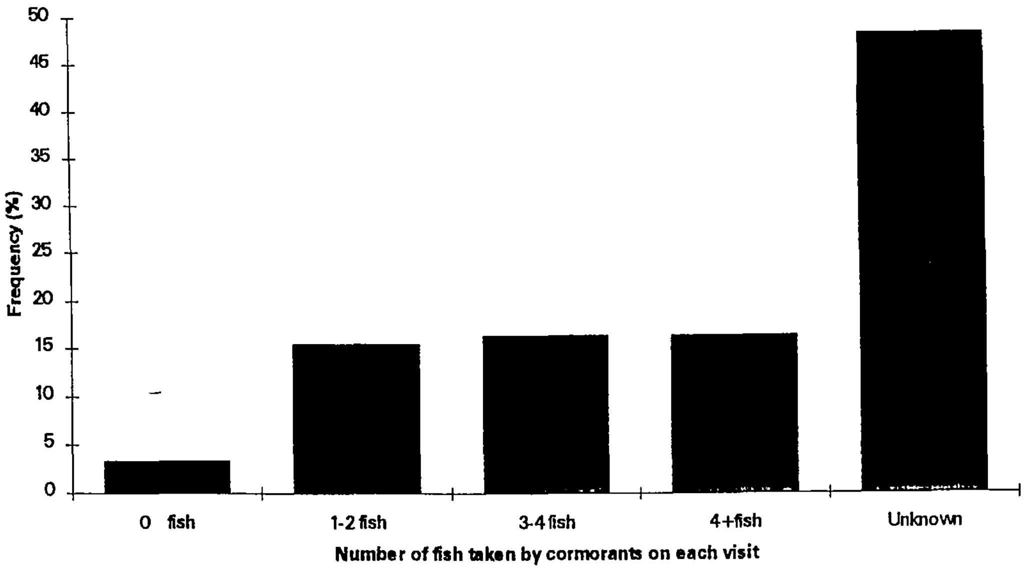


Figure 3.7. The reported numbers of fish eaten by cormorants per visit to still waters in the Lea and Colne valleys. N = 122 records.

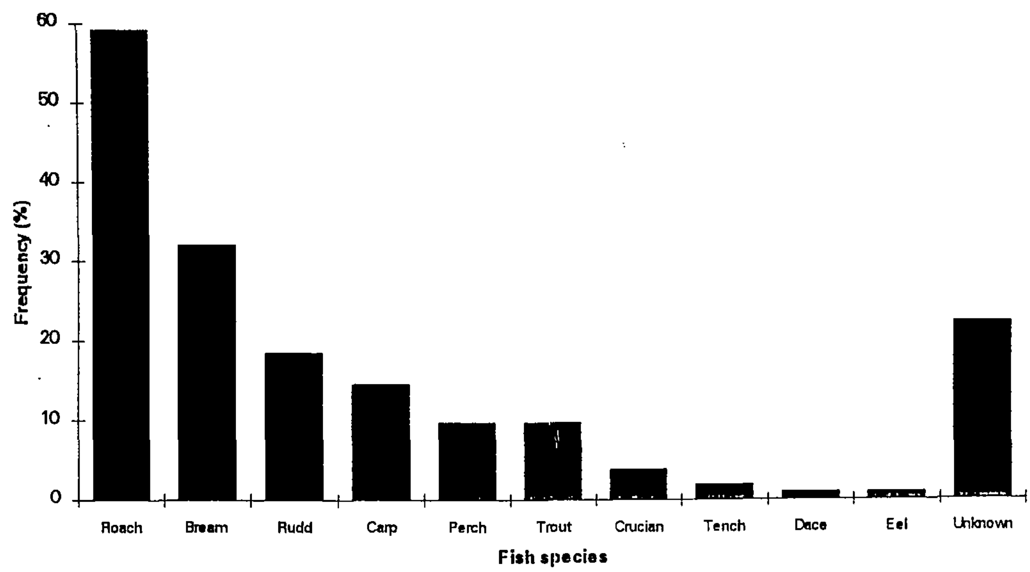


Figure 3.8 The reported species of fish eaten by cormorants at still waters in the Lea and Colne valleys. Data for each species are expressed as % of all records (N = 122).

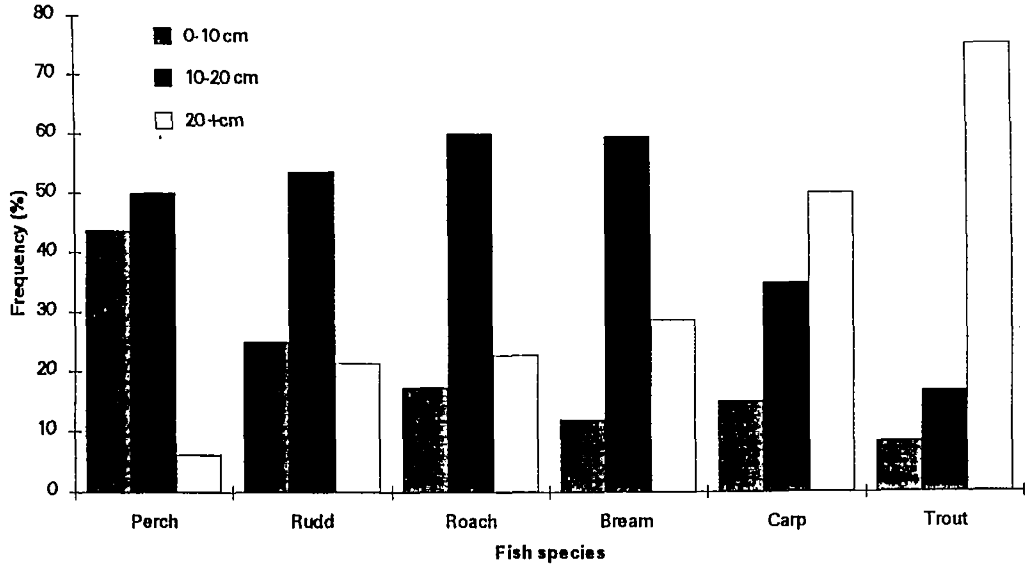


Figure 3.9. The reported sizes of different fish species eaten by cormorants at still waters in the Lea and Colne valleys. N = 93 records.

now being stocked at stillwaters in the Lea and Colne valleys in addition to any depredation.

The most commonly reported stocked species from the questionnaire returns were, in rank order; roach, bream, carp, tench and trout, with fewer reports of rudd and crucians and the occasional stockings only of perch, pike and other species (e.g. orfe) being reported (Figures 3.10 and 3.12). Data on the stockings in the whole survey area, however, (i.e. including waters for which no questionnaire returns were available) show a significantly different rank order namely; carp, roach, rudd, bream, tench, trout and crucians, with few perch or pike (Table 3.4). In particular, less carp and trout were reportedly stocked by respondents than in the area as a whole but more bream were stocked. The other species were similar with respect to the proportions of total stockings in each sample.

Carp and tench both appeared to be caught more often now than in the past and both were commonly stocked, carp especially so (Figures 3.10 and 3.12, Table 3.4). Roach, however, though one of the most commonly stocked species, no longer appears to be one of the main species caught by anglers at most stillwaters in the Lea and Colne valleys. Figures 2.11 and 2.13 show the most commonly reported species caught by cormorants at the stillwater sites where changes in the species caught by anglers were reported. Cormorants were reported to take roach most commonly , followed by bream, rudd and carp but proportionately fewer crucians and tench (Figures 3.11 and 3.13). In addition, in the experimental lagoons discussed in Section 2.1.1, roach and bream suffered proportionately greater mortality compared to carp in both the control lagoon ('natural' post-stocking mortality) and the test lagoon (bird depredation).

3.3 Discussion

Although not all stillwaters in the Lea and Colne valleys were visited by cormorants (13.5% in this survey) it was not possible to establish from the questionnaire survey what proportion of the total number of stillwaters in the area had or did not have a cormorant presence. This is because questionnaire returns could theoretically be biased towards stillwaters with cormorants rather than the reverse. Put simply, it could be argued that people were more likely to have returned a questionnaire if they believed they had a cormorant problem than if they did not. Marquiss and Carss (1995), however, found that in their national UK survey on the potential problems of fish-eating birds at inland fisheries, regions that returned a high number of questionnaires did not contain a significantly different proportion of respondents claiming a problem with fish-eating birds than regions that returned many fewer questionnaires. Unfortunately, these findings could be interpreted either as demonstrating no bias in questionnaire returns or equally demonstrating a consistent one.

Notwithstanding the above difficulties it remains clear that not all stillwaters have, at the moment, any obvious cormorant presence and the extent to which cormorants may or may not 'expand' into these waters is worthy of comment. The historical data suggests that in recent years the expansion to new sites in the area has slowed slightly (Figure 3.1) as fewer than 6% of respondents reported recent 'colonization' by cormorants (i.e. within the past two years). Although both the number of inland breeding and wintering cormorants is known to be increasing (Russell *et al.* 1996) there are no published data on local changes in colonization rates or patterns with which to compare the present survey data. The

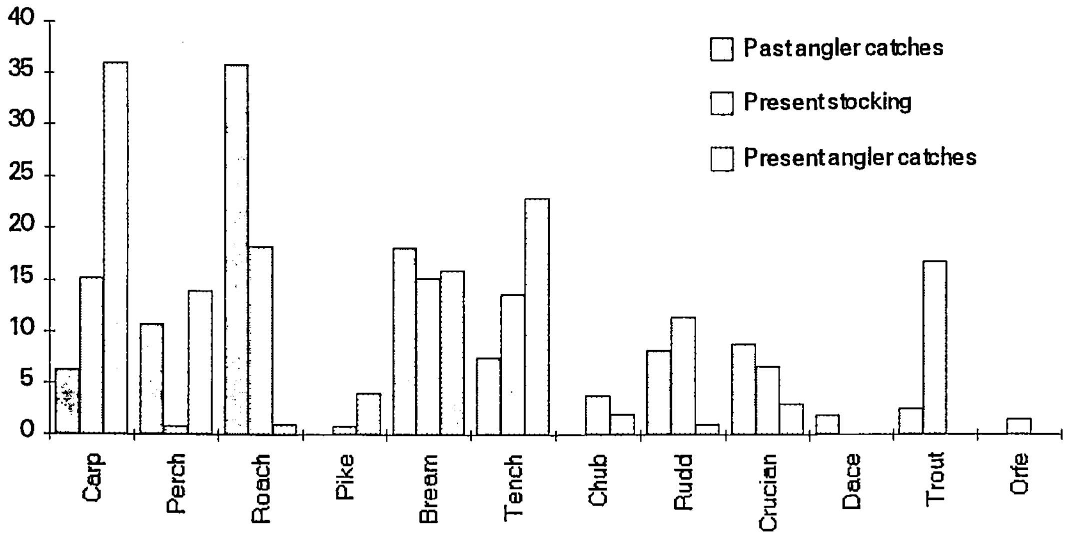


Figure 3.10 Reported changes in the main species of fish caught by pleasure anglers at still waters in the Lea and Colne valleys during the past 2-3 years and the species stocked during that time.

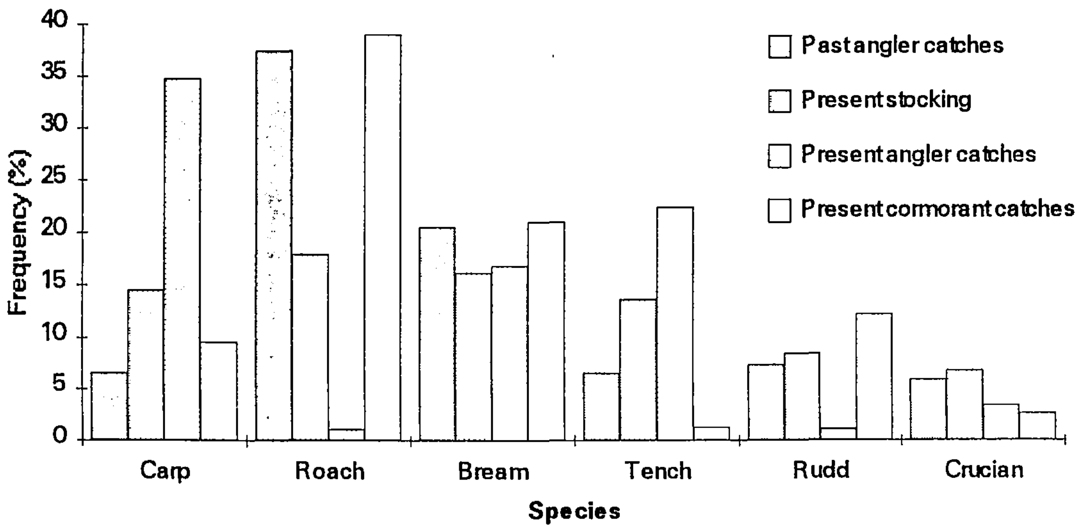


Figure 3.11 Past and present pleasure angler catches in relation to the most commonly reported prey species of cormorants visiting still waters in the Lea and Colne valleys. Data are for the six most commonly stocked coarse fish species.

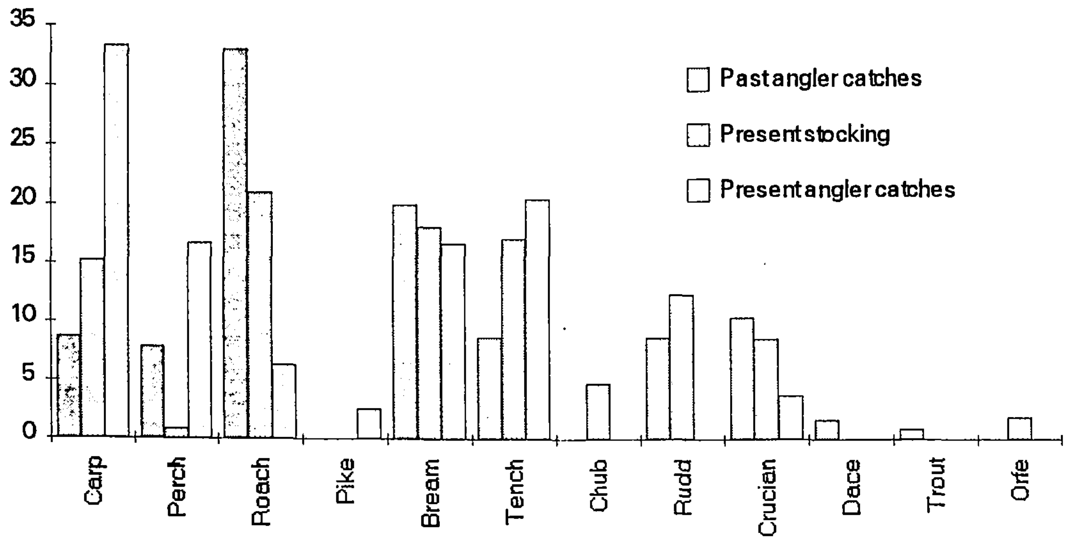


Figure 3.12 Reported changes in the main fish caught by match anglers at still waters in the Lea and Colne valleys during the past 2-3 years and the species stocked during that time.

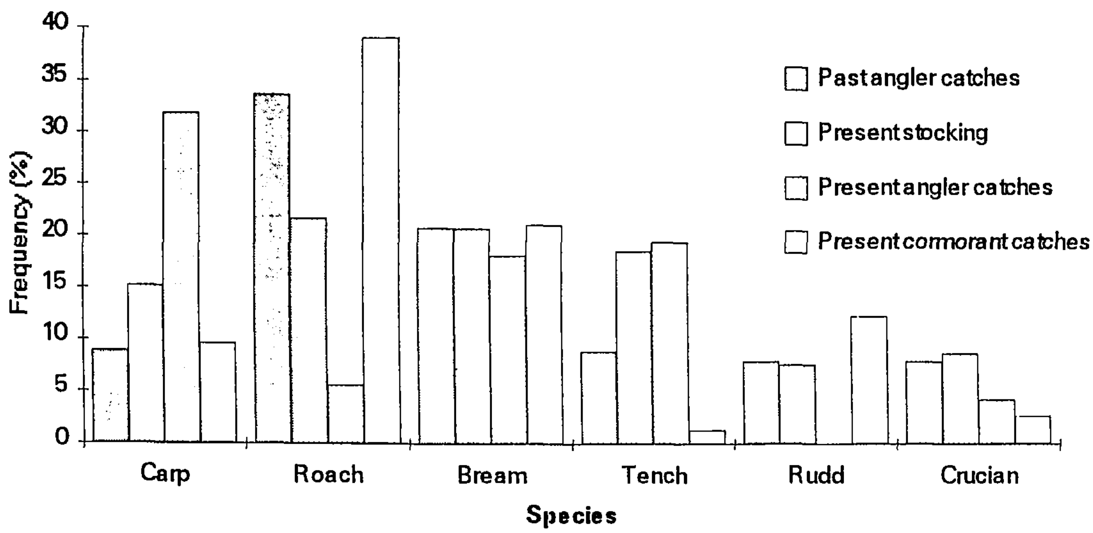


Figure 3.13. Past and present match angler catches in relation to the most commonly reported prey species of cormorants visiting still waters in the Lea and Colne valleys. Data are, again, for the six most commonly stocked coarse fish species.

Table 3.4 Stockings in the whole Lea and Colne valley survey area, including data from stillwaters for which no questionnaire returned were available. Data are for April 1995 and February 1997 (χ^2_8 = 6.632, ns).

	April 1995 - March 1996		April 1996 - February 1997	
	No. of stockings	% of total stockings	No. of stockings	% of total stockings
Roach	44	16.7	26	13.3
Carp	73	27.7	60	30.6
Bream	32	12.1	18	9.2
Tench	25	9.5	27	13.8
Perch	10	3.8	8	4.1
Rudd	35	13.3	25	12.8
Pike	8	3.0	2	0.9
Crucians	18	6.7	17	8.7
Trout	19	7.2	13	6.6
TOTAL	264	100.0	196	100.0

Questionnaire survey v April '95- March '96; χ^2_8 = 17.585, $p < 0.05$
Questionnaire survey v April '96- February '97; χ^2_8 = 21.117, $p < 0.01$

likelihood of this trend continuing depends on a number of factors including for example, changes to stocking regimes and the establishment of new fisheries and/or changes in the number of cormorants visiting current sites and the establishment of inland breeding colonies.

3.3.1 Numbers of cormorants in relation to water body size.

If the estimates of cormorant numbers provided by respondents are accurate they represent an enormous difference in the apparent capacity of small stillwaters to attract cormorants which, in turn, may suggest potential management strategies for reducing bird presence if the factors leading to these differences were to be established by future studies. It may, however, be more appropriate to view the apparent variance in these data as being rather more due to sampling error than of great ecological significance as other studies have shown that people differ greatly in their estimates of bird abundance, even at the same site (Callahan *et al.* 1994). Data for some sites in the current study were available from three independent sources which provided the opportunity to examine this further (Table 3.5).

These data showed that even when fairly broad abundance bands were given to respondents, the choice of band was not consistent and that the ranges in these estimates could vary between 9 - 34+ (Table 3.5). Respondents were not, however, asked to count birds in a particular way nor explain the derivation of their estimates. The variation in estimates could reflect, therefore, a large range of different factors including, for example, the frequency and duration of visits to the site by respondents and when these occurred together with the possibilities of double counting birds etc. Thus, although the general picture for water bodies of various sizes is likely to be broadly accurate (Figure 3.3), it is not possible to say to what extent variation in abundance estimates at stillwater sites reflects real ecological differences or simply differences in how these estimates were derived.

3.3.2 Seasonal variation in stillwater occupancy.

The patterns of cormorant occupancy suggested by the questionnaire replies are consistent with the findings from the Rye Meads experiment and other studies The general 'winter high, summer low' pattern has been reported from a number of stillwaters in the north-west, midlands and south-east (Davies 1997, Cowx *et al.* 1996, Marquiss and Carss 1995, Feare 1988) and is consistent with birds returning to the coast to breed. In areas without local inland breeding colonies this pattern is likely to be the norm with few birds remaining at sites during the summer months. Other seasonal patterns of occupancy have also been reported. For example, in areas with nearby inland colonies, occupancy at some sites may remain high throughout the year and the exclusive use of some sites during certain parts of the year may be linked to differences in the profitability of these sites. These suggestions too are consistent with some of the reports from the Lea and Colne valleys where there are many stillwaters cormorants might choose to visit presumably in response to spatial and temporal variation in their prey (Davies 1997, Cowx *et al.* 1996). In the Ribble Valley, Lancashire for example, where there are few stillwaters, cormorants instead appear to use different parts of the river at different times of year and in doing so experience different food intake rates (Davies and Feltham 1995). Such movements in this and other fish-eating birds have been attributed to seasonal changes in fish availability associated with for

Table 3.5 Variation in the [1]categorised estimates of cormorants at 8 stillwater sites in the Lea and Colne valleys.

Site	Area (ha)	Estimate 1	Estimate 2	Estimate 3	Possible range
Site #008	8.1	11-15	1-4	5-10	1-15
Site #026	2.0	11-15	11-15	5-10	5-15
Site #053	3.2	5-10	5-10	11-15	5-15
Site #068	15.4	11-15	5-10	16-20	5-20
Site #072	4.0	50+	21-30	16-20	16-50+
Site #088	1.2	5-10	11-15	11-15	5-15
Site #091	4.9	1-4	5-10	1-4	1-10
Site #098	2.0	16-20	11-15	16-20	11-20

[1]Categories respondents were asked to choose to best represent cormorant abundance at their site

example, spawning in cyprinids or smolt migrations in salmonids (Davies 1997, Feltham and McLean 1996, Feltham 1995, Feltham 1990).

3.3.3 Diurnal variation in stillwater occupancy

The existence of a dawn (and to a lesser extent, a dusk) peak in the foraging activities of cormorants as reported by the anglers and fishery managers surveyed is well know (e.g. Davies 1997) and generally assumed to be the most common diurnal pattern for these birds. Cormorants can and do, however, feed at any time of the day and this was also reported. A few sites showed a marked midday peak and it may be that these are sites (or in the case of the Rye Meads lagoons, site complexes) that are used primarily as day roost and only secondarily as feeding areas (see e.g. Cowx *et al.* 1996). In other cases birds may both feed and roost at the same site and so be present all day (see e.g. Feare 1988). It is interesting that all of these patterns of occupancy were found in the questionnaire survey.

3.3.4 The numbers of fish taken by cormorants

Whilst the seasonal and diurnal patterns of occupancy reported from stillwater sites in this study were consistent with the patterns reported elsewhere, reports of fish consumption were not. The frequency distribution generated from the respondents estimates of consumption (Figure 3.7) was skewed to the right i.e. the greatest proportion of respondents estimated that 3 - 4+ fish were taken per visit and hardly any reported that no fish were taken. In marked contrast, however, detailed observations of the individual foraging bouts of cormorants have shown that the number of fish they consume during a visit to a foraging area is regularly skewed to the left i.e. they typically catch few fish per visit and often none at all (Section 2.2.3 of the Rye Meads experiment, Davies 1997, Cowx *et al.* 1996). Although the questionnaire asked respondents to base their estimates of consumption on observations, these data would appear to suggest that some estimates could have been influenced by expectations, extrapolations or assumptions about likely intake and are hence less empirical than had been hoped.

3.3.5 The species of fish taken by cormorants

All 11 species reportedly taken by cormorants from the questionnaire survey have previously been reported as prey items from British stillwaters with the exception of rudd (Russell *et al.* 1996, Feltham and Davies 1995, McCarthy *et al.* 1993, Kennedy and Greer 1988, MacDonald 1987, Mills 1965, Hartley 1948). Rudd however has been reported as a prey items in many studies in the Netherlands, though generally it comprises < 1% of the diet (Dirksen *et al.* 1995, Koffijberg and van Eerden 1995, Veldkamp 1995). The frequencies with which different species were reported as the main species eaten by cormorants at Lea and Colne stillwaters may, however, reflect three things (i) a preference for certain species by these birds (ii) the natural availability of different fish species in the waters surveyed and (iii) the levels of stocking of different species.

3.3.6 The sizes of fish taken by cormorants

The most commonly reported overall size range of fish taken by cormorants from the stillwaters of the Lea and Colne valleys (10 - 20 cm) was close to that indicated by previous scientific studies on cormorant depredation of cyprinids (Russel *et al.* 1996, Feltham and Davies 1995, McIntosh 1978) but towards the lower end of that indicated by studies on trout depredation (Russell *et al.* 1996, Ransom and Beveridge 1983, Rae 1969, Mills 1965). As the majority of sites in the survey were coarse fisheries this is perhaps not surprising. At many sites fish of different sizes were taken and this no doubt partly reflected different species compositions at the sites as there was some variation in the sizes of fish taken by birds with respect to species. The species specific size ranges reported to be taken most often by cormorants from the questionnaire were also consistent with previous studies; roach, rudd and bream of 10 - 20 cm, small (< 10 cm) and medium/large perch (10 - 20 cm) and 20+ cm trout. With respect to carp, however, previous studies (Russell *et al.* 1996) suggest proportionately fewer fish of 20+ cm are taken than suggested by the current study. These differences, however, most probably reflect simply local differences in the sizes of carp available to cormorants which in turn no doubt reflects stocking regimes in the area (see Sections 3.3.8 and 3.3.9).

3.3.7 Recent changes in the numbers of fish caught by anglers

The overwhelming consensus was that a reduction in the numbers of fish being caught by pleasure anglers (81.7% of records) and match anglers (89.4% of records) had occurred during the past 2 - 3 years. Such reports are common place and are, moreover, often attributed to depredation by birds, most notably cormorants. Without, however, obtaining historical match records for the sites surveyed it is not possible to tell (i) if the perceived reduction in catch is real or (ii) whether this is wholly or partly due to bird depredation. Even when a decline in catches can be demonstrated from historical data it cannot be assumed that the mere presence of predators means that they are responsible, as the following example demonstrates. Davies (1997) compared angler catch data on the River Ribble to levels of depredation on fish stocks by cormorants. Far from finding angler catches to be low when cormorant depredation was high and found the two to be positively correlated. In other words, when anglers were successful cormorants were successful and *vice versa* suggesting both birds and anglers were responding to changes in the availability of fish and not causing them.

3.3.8 Recent changes in the sizes of fish caught by anglers

A number of points raised by the responses to this part of the questionnaire are worthy of note. First, both pleasure and match anglers have noted marked changes in the sizes of fish they have been catching over the past 2 - 3 years. Second, there are significant differences between the changes in size of fish caught by pleasure anglers and those caught by match anglers. Third, these shifts are not consistent between water bodies. The patterns may be approximately summarised from Section 2.3.8 as follows; pleasure anglers - 42% report a shift towards larger fish being caught and 38% report a shift towards smaller fish, match anglers - 63% report a shift towards larger fish being caught and 30% report a shift towards smaller fish. In addition to these questionnaire data it has been noted that middle sized fish have been absent from some Colne Valley lakes after extensive fish kills by pollution (Pilcher, M. personal observation). There are a number of possible explanations for these findings.

First, as cormorants tend to eat mostly fish of < 20cm any significant depredation effect would be expected to result in a fish population skewed either towards larger individuals, very small newly recruited individuals or both. If this was the case, however, it is unclear why both match and pleasure anglers did not report similar changes in the sizes of fish caught in recent years on the same waters. Any natural mortality that might disproportionately affect certain size classes of fish might also result in a population comprising disproportionate numbers of certain size classes of fish (see e.g. Section 2.2.1, Riemens 1985, Riemens 1984).

Second, match anglers may catch larger fish now compared to pleasure anglers because they frequent venues that are stocked with larger fish, whilst pleasure anglers may be less selective. In other words, if match weights are important then providing a well stocked fishery is likely to be equally important. Stocking with species that grow to a large size (e.g. carp, bream) or large individuals of typically smaller species (e.g. roach) would be one way of achieving this. There were, however, insufficient data to look at the relationship between size of stocked fish and recent changes in the sizes of fish caught by anglers. There is, however, an anomaly with the stocking hypothesis: the vast majority of stillwaters in the survey are used for **both** pleasure angling and matches which suggests that both types of anglers should have experienced similar changes in the sizes of fish caught in recent years.

3.3.9 Recent changes in the species of fish caught by anglers

The questionnaire survey showed there has been a perceived shift in the species caught by anglers in the Lea and Colne valleys in recent years, **from** roach, small-medium sized bream, perch and rudd **to** carp (particularly large ones), tench and large bream. The reasons for these changes appear, however, to be complex. The data suggest that there is no single overwhelming factor responsible for these changes, rather a combination of interacting factors may be responsible, particularly for the apparent decline in roach and increase in carp catches. These factors include, (i) the species being stocked in the area, (ii) bird depredation and (iii) differential mortality of wild and stocked fish.

Active bottom feeding by these fish and others such as large bream will result in an increase in year round water turbidity, the loss of submerged plant-life and the loss of more fragile fish species which cannot compete. In short, an attempt to promote stillwater angling by stocking large 'predator proof' species could in the medium to long term do more harm to a fishery than the predators could do alone.

This presents fishery owners with somewhat of a dilemma; if the magnitude of post-stocking mortality of small roach and bream is high (see Sections 2.1.1 and 2.3) and, in addition, the mortality of these species from a variety of bird predators is similar, continued stocking with these fish is unlikely to benefit the fishery. Conversely the increasing practice of stocking large carp could eventually result in the serious degradation of many small stillwaters. This is because carp, although seemingly more robust and less prone to depredation (especially large fish) tend, as do large bream, to stir up the sediments in lakes in search for food (thus increasing turbidity). In doing so they also root up macrophyte seedlings and can fuel algal blooms by releasing plant nutrients (Anonymous 1992, Meijer, Raat and Doef 1989, Ten Winkel and Meulemans 1984). If the preference for stocking carp in shallow stillwaters of < 5 ha continues (Table 2.5), this could eventually result in the serious degradation of many lakes. Active bottom feeding by carp and bream populations will result in the loss of submerged plant-life, loss of more fragile fish species (e.g. roach) which cannot compete and an increase in year round water turbidity (see e.g Angling Times, 18.6.97 pg14). In short, an attempt to promote stillwater angling by using 'predator proof' species like carp and larger bream could in the medium to long term do more harm to a fishery than the predators could do alone.

3.4 Conclusions and Recommendations

The questionnaire survey was extremely useful in gaining an overall picture of two things (i) anglers' views on present cormorant numbers and feeding habits in the Lea and Colne valleys and (ii) perceived changes in the number, species and sizes of fish being caught by anglers during the past 2-3 years.

The questionnaire data on cormorant occupancy patterns at stillwaters in the Lea and Colne valleys was comparable to those reported in the scientific literature. The questionnaire survey, however, also provided information on the relative frequencies of the different patterns of cormorant occupancy. This is a useful first step in trying to find out why it is that cormorants visit some sites at certain times of the year/day and others at different times. If this was known it would enable the management options for these sites to be more clearly formulated.

Similarly, the species and sizes of fish reportedly taken by cormorants in the Lea and Colne valleys were comparable to those in the literature and again provided a useful insight into current feeding habits of these birds. This is particularly important because it means that any perceived shifts in angler catches can be examined in relation to perceived bird depredation and put into context. Context is the key word here, because the questionnaire survey also provided information on stocking practices and showed that these too need to be taken into account when trying to explain perceived changes to angler catches.

Whilst the questionnaire provided, therefore, useful qualitative information on local patterns of cormorant behaviour and angler catches it did not provide information that was reliable enough to be used quantitatively to assess impact at stillwaters in the Lea and Colne valleys. This was for three main reasons.

First, it was not possible to tell what proportion of stillwaters had a cormorant presence. This was because there was no means of ensuring that questionnaire returns were not biased against sites that contained no cormorants. Following up non-replies by telephone is perhaps the most effective way of maximizing returns but is also both labour intensive and expensive.

Second, good estimates of cormorant numbers are required for impact estimates. Count data showed, however, enormous variance both within and between sites making reliable abundance estimates difficult. This is not, perhaps, surprising because respondents were not asked to collect the data in a coordinated way, just to report their own views. Whilst these are likely, in the majority of cases, to have been based on personal experience estimates will inevitably vary. Clearly, estimates based on a large number of daily bird counts carried out at the same time of day are likely to be far more accurate than *ad hoc* rough estimates made whilst 'walking the dog'. Standardizing cormorant counts at stillwaters would be a major task.

Third, estimates of the numbers of fish eaten by cormorants from the questionnaire survey were one of the few that were demonstrably different to those found both in the Rye Mead experiment (Section 2.0) and reported in the scientific literature. This too may not be surprising because without detailed field observations estimating the numbers of fish consumed by cormorants is difficult and respondents were asked only for their views not detailed data. It is, nonetheless, interesting that the two kinds of data that have greatest bearing on estimating the amount of fish removed by cormorants (namely how many birds there are at a fishery and how much they eat), were the two that appeared least robust from the questionnaire survey. Data that had less direct bearing on impact estimates (e.g. patterns of occupancy, species and sizes of fish eaten) agreed reasonably well with published scientific studies.

Finally, it should be noted that the perceived changes in the numbers, sizes and species of fish being caught by anglers were not independently assessed from catch records held by angling clubs. Put simply, at present there is a suggestion that we may be experiencing a shift in angler catches from roach and small bream towards larger bream and carp in the stillwaters of the Lea and Colne valleys. Catch record analysis would be the obvious way to confirm or deny this. Given the serious implications of such a shift the Agency might do well to consider repeating the questionnaire survey, perhaps every three years, in order to monitor the situation.

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