INSTITUTE OF TERRESTRIAL ECOLOGY
(NATURAL ENVIRONMENT RESEARCH COUNCIL)

ITE Project T135c1

Report to Scottish Natural Heritage, formerly the
Nature Conservancy Council for Scotland
Contract No. 09,F2A,237

CORMORANTS AND THE LOCH LEVEN TROUT FISHERY

D.N. CARSS & M. MARQUISS

BANCHORY RESEARCH STATION
Hill of Brathens
BANCHORY
Kincardineshire
AB31 4BY

May 1992

CONTENTS

SUMMARY

1. The possible conflict between cormorants (*Phalacrocorax carbo*) and the brown trout (*Salmo trutta*) sport fishery at Loch Leven, Kinross, was investigated in the spring of 1992, using the available historic data together with recent counts and stomach samples.

2. The angled trout catch declined dramatically after 1989, the best season for over twenty years. However, a low catch was not unprecedented; similar catches had occurred four times in the last twenty years.

3. From 1983, increasing numbers of hatchery-reared trout have been released into the loch. Fish were unmarked and their fate, and possible interactions with wild bred fish, are unknown.

4. The trout and perch populations were studied in detail between 1969-1972 as part of the International Biological Programme (IBP). There has been little further work and the population dynamics of current trout and perch populations are unknown.

5. Trends in the numbers of cormorants wintering in Scotland are unknown but the numbers breeding have declined from 3400 pairs in 1969-1970 to 2900 pairs in 1985-87, though small numbers at some east coast colonies increased between these two surveys. Over-wintering cormorants at Loch Leven have increased three-fold since the 1987-1988 winter and numbers are now generally higher in the spring than the autumn. A maximum of 800 birds were counted in February 1991. The age structure and provenance of this population is discussed.

6. Annual and seasonal variations in cormorant counts at Loch Leven were compared with those on other water bodies, as revealed by 'wildfowl counts'. Fisheries managers and angling club secretaries throughout Scotland were contacted about the perceived cormorant problems at other stillwater fisheries.

7. Cormorant diet at Loch Leven was assessed from three different samples collected between 1971-1992. The proportion of birds containing trout increased significantly over this period, whilst those containing perch declined. Only two birds from the spring 1992 sample (n = 20) had eaten perch.

8. The large numbers of cormorants at Loch Leven are likely to have consumed large numbers of trout, many of which were big enough to be taken by anglers. There is the potential for conflict between the birds and the fishery, although the true impact of the birds is unknown.

9. Methods of deterring cormorants from fisheries, stock practices and aspects requiring further study are reviewed and discussed.

1. INTRODUCTION

This report is a preliminary investigation into the possible conflict between cormorants (*Phalacrocorax carbo*) and the brown trout (*Salmo trutta*) sport fishery at Loch Leven, Kinross, eastern Scotland (Fig. 1). The loch is a shallow nutrient-rich lowland water body with an area of 13.3 km^2 and a mean depth of 3.9 m, it has been a National Nature Reserve since 1964, is renowned for its wildfowl and was one of the original 13 sites designated by the UK under the Ramsar convention. The loch is of international importance for pink-footed geese (*Anser brachyrhynchus*) and greylag geese (*A. anser*), and of national importance for whooper swan (*Cygnus cygnus*) and several duck species (Owen *et al.*, 1986).

Loch Leven is also a world-famous brown trout fishery, but catches have declined in recent years. In the popular literature many factors have been suggested (though little substantiated) for this decline including, algal blooms, high phosphate and nitrate run-off from surrounding farmland, an alteration of trout feeding habits from surface to benthic feeding, a reduction in water flow as a result of nearby gravel extraction, a decline in the perch (*Perca fluviatilis*) population and increased cormorant predation.

Cormorants regularly use Loch Leven as a feeding and roosting site and the apparent increase in their numbers has given rise to potential for conflict with the trout fishery run by Kinross Estate Company. In recent years cormorant numbers on the loch have exceeded 200 reaching levels of national importance (see latest Wildfowl at Wader Counts, published jointly by the Wildfowl Trust and the British Trust for Ornithology, for current qualifying level), but their impact on the fishery is unknown. The Estate are so concerned about such a potential impact that they are seeking permission to control cormorant numbers. The present report is a review of current knowledge of cormorants at Loch Leven and the possible management implications for the trout fishery there.

2. AIMS

The present study has several aims:

(1) To examine the existing data on the fish populations of the loch to search for any possible implications for the cormorant population.

(2) To review data on cormorant numbers at Loch Leven and nationally, to discern population trends, if any.

(3) To search for external effects which may influence cormorant use of the loch using the available cormorant counts from nearby lochs and 'roosts'.

(4) To analyse data on the stomach contents of cormorants collected at Loch Leven over the last 21 years (1971-1992) to search for trends in diet.

(5) To assess, if possible, the extent of predation on trout by cormorants, and the implications for the trout fishery.

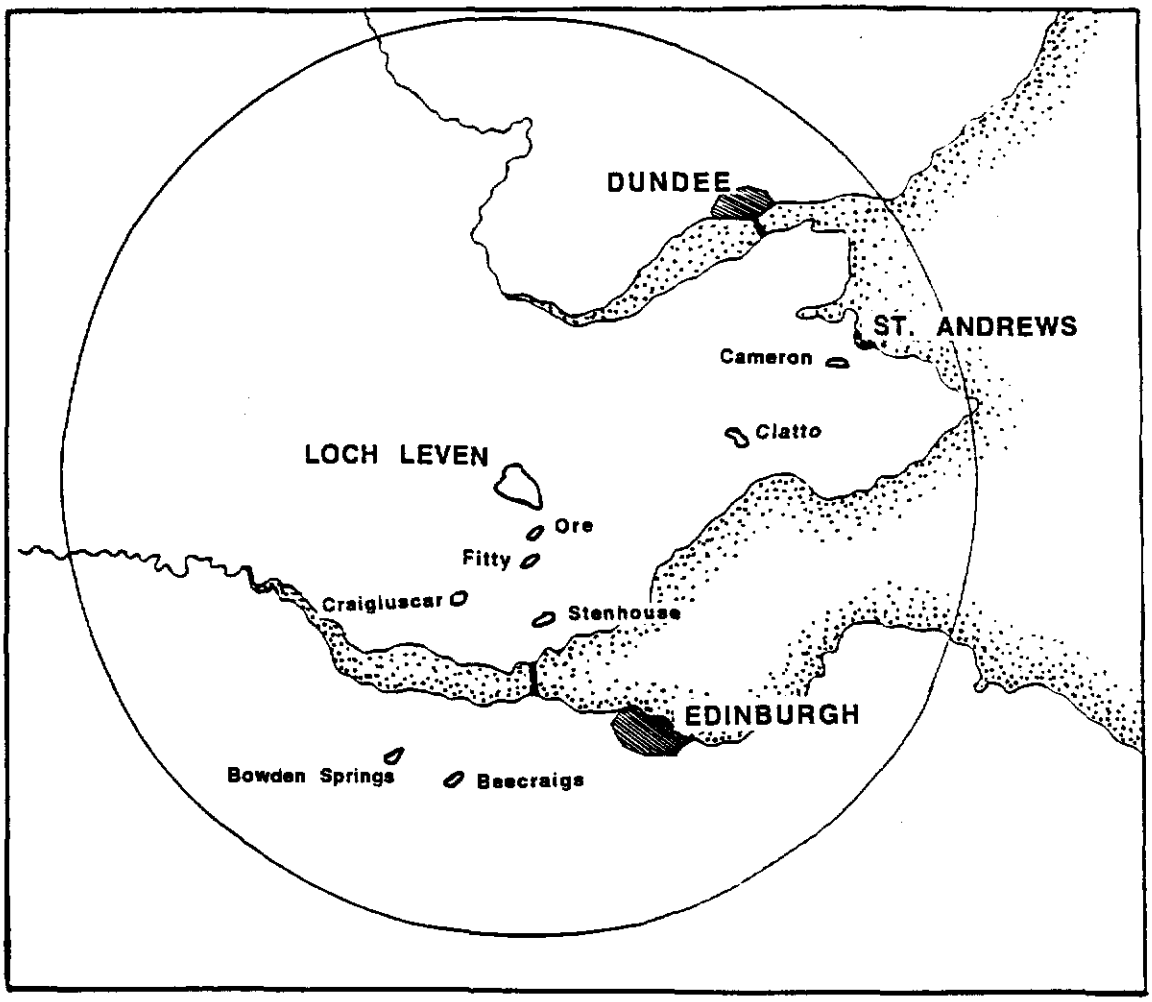

Figure 1. Map showing the location of Loch Leven and other fisheries mentioned in the text. Circle indicates area within 50km of the loch.

(6) To review the literature on methods of deterring cormorants from fisheries.

(7) To look at alternative methods of restocking large water bodies with the objective of reducing cormorant predation.

(8) To identify aspects of this study which require further work.

3. THE LOCH LEVEN TROUT FISHERY

3.1 Catch Statistics

Loch Leven is arguably the most famous and productive trout loch in the world (Sandison, 1992). Angling catches have been recorded for well over a century (Morgan, 1974). From 1922 to 1944 the annual catch varied between 25 000 and 60 000, after which it declined to about 15 000 in 1947 before increasing steadily to 86 000 in 1960. Thereafter, catches again decreased and only 9571 trout were landed in 1971. Recent statistics (Fig. 2) show that although catches were high in some years they never reached the peak levels of the 1950s and 1960s. The best season for over twenty years was 1989, since when there has been a decline but this was by no means unprecedented.

Associated with the recent decline in trout catches is a perception that the size of the fish caught has increased, a trend not apparent in the catch statistics (Fig. 3). However, one possible reason for this is that the catch statistics as presented do not take into account the frequency distribution of fish weights. Anecdotal evidence suggests that recent landings have been characterised by catches of some very small fish of takeable size (ca. 9ins, 23 cm) or smaller and some very large, many weighing more than 5lbs (2.27 kg) and including the largest on record (8lbs 3oz, 3.71 kg) (Muckle, 1991).

3.2 Stocking Policies

The loch was apparently stocked intermittently after 1873, however, this stopped in 1935 (Morgan, 1974). The loch was not stocked gain until 1983 when a programme of releasing hatchery-reared Loch Leven trout was initiated. Over 880 000 3-6 inch (7-15 cm) trout have been released to date (Fig. 4). Releases took place during September in 1983 and 1984, May and August in 1985, April in 1986-1990 and April and August in 1991. Fish are apparently released in one large batch at one site in the loch. Irregular stocking of the feeder streams has also taken place. Up to 200 000 'green eggs', 'eyed eggs' and 'point of feed' fry have been released in years when there has been a surplus produced at the hatchery.

3.3 Fish Population Studies

The trout and perch populations of the loch were intensively studied between 1969-1972 as part of the International Biological Programme (IBP). Annual production of trout was estimated to be 2.2 - 3.9 g (wet wt.) m^{-2}, and of perch 5.1 - 67.4 g (wet wt.) m^{-2} (Thorpe,

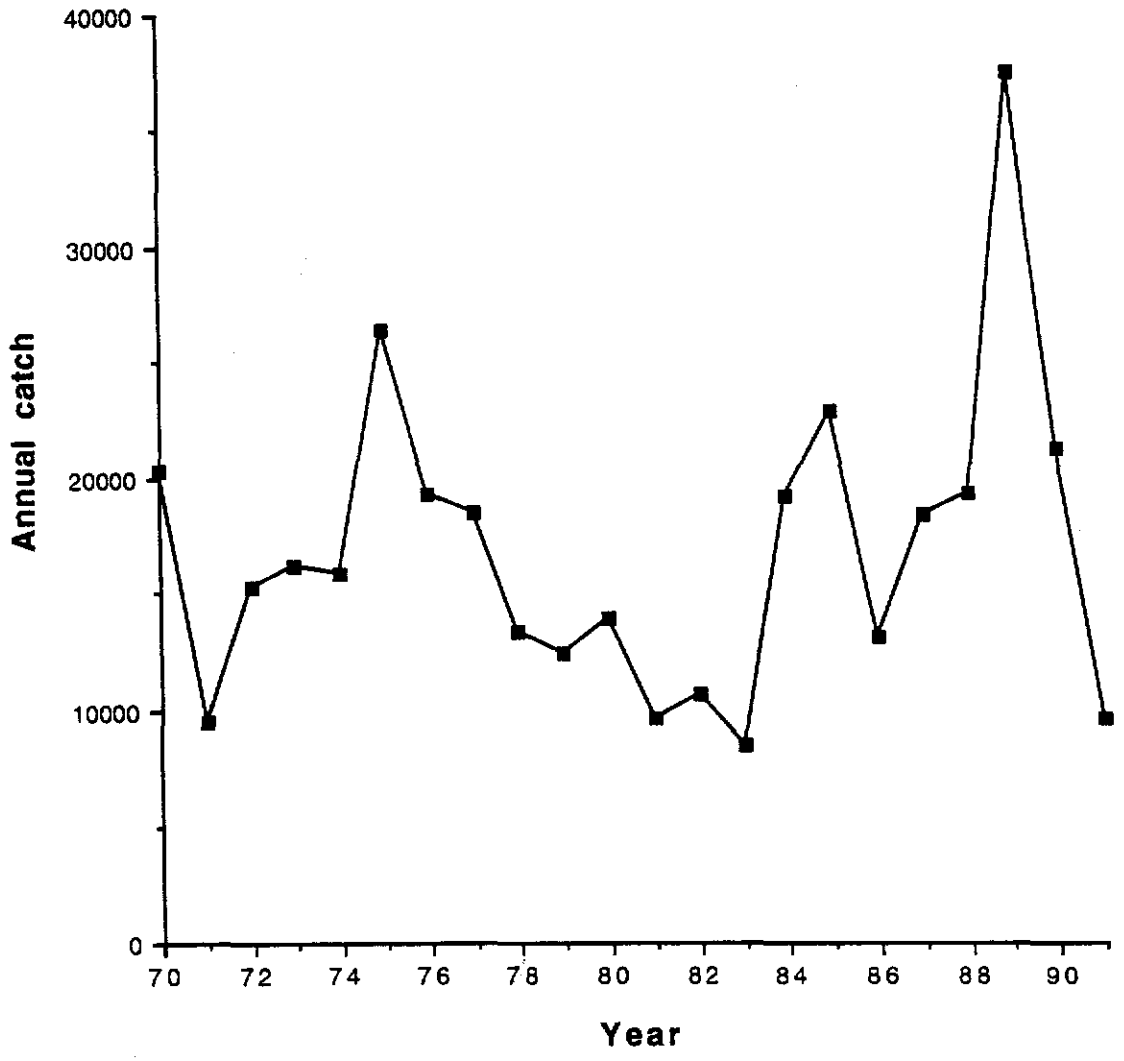

Figure 2. Annual trout catches at Loch Leven, 1970-1991.

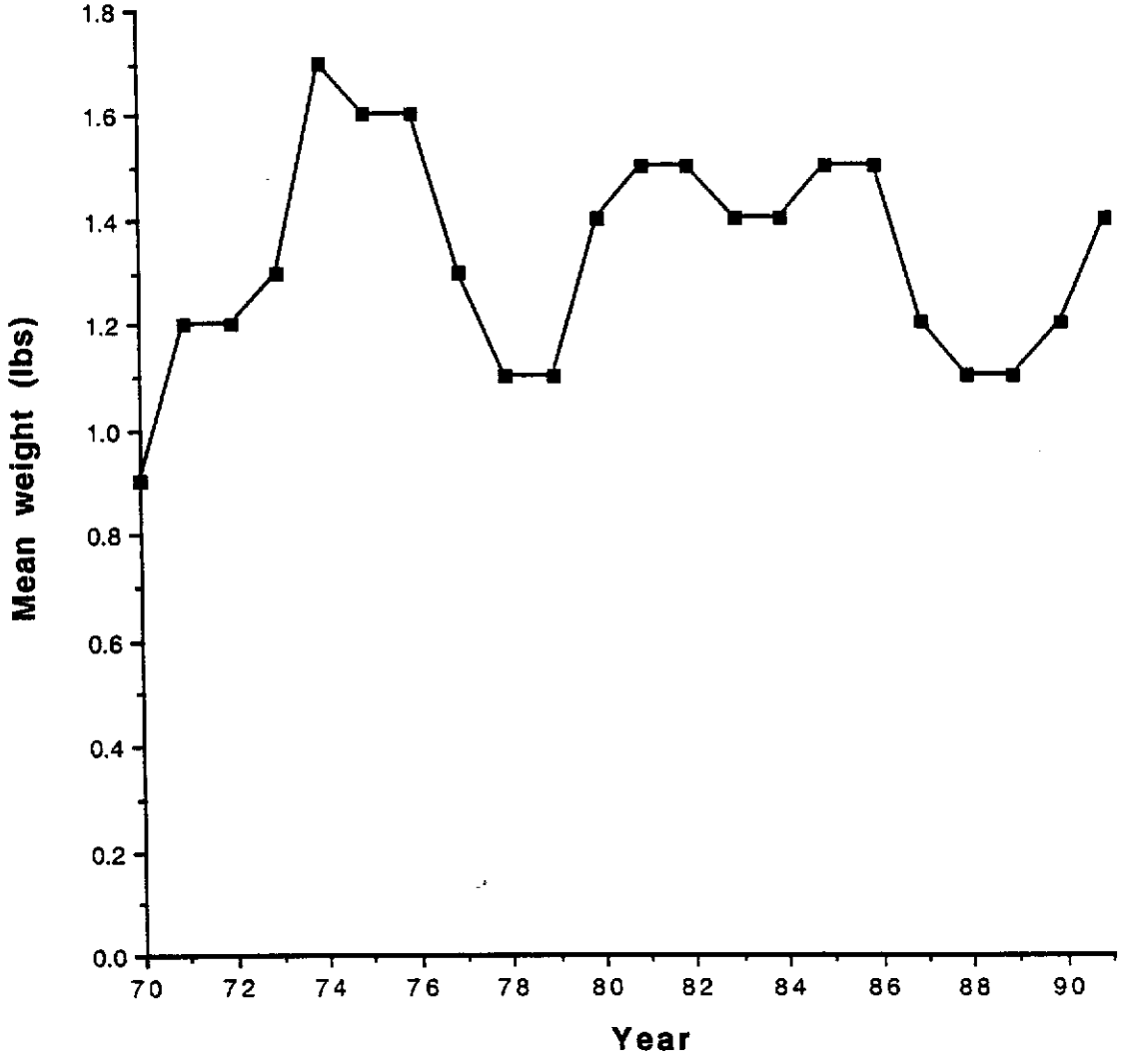

Figure 3. Mean weight of trout caught at Loch Leven, 1970-1991.

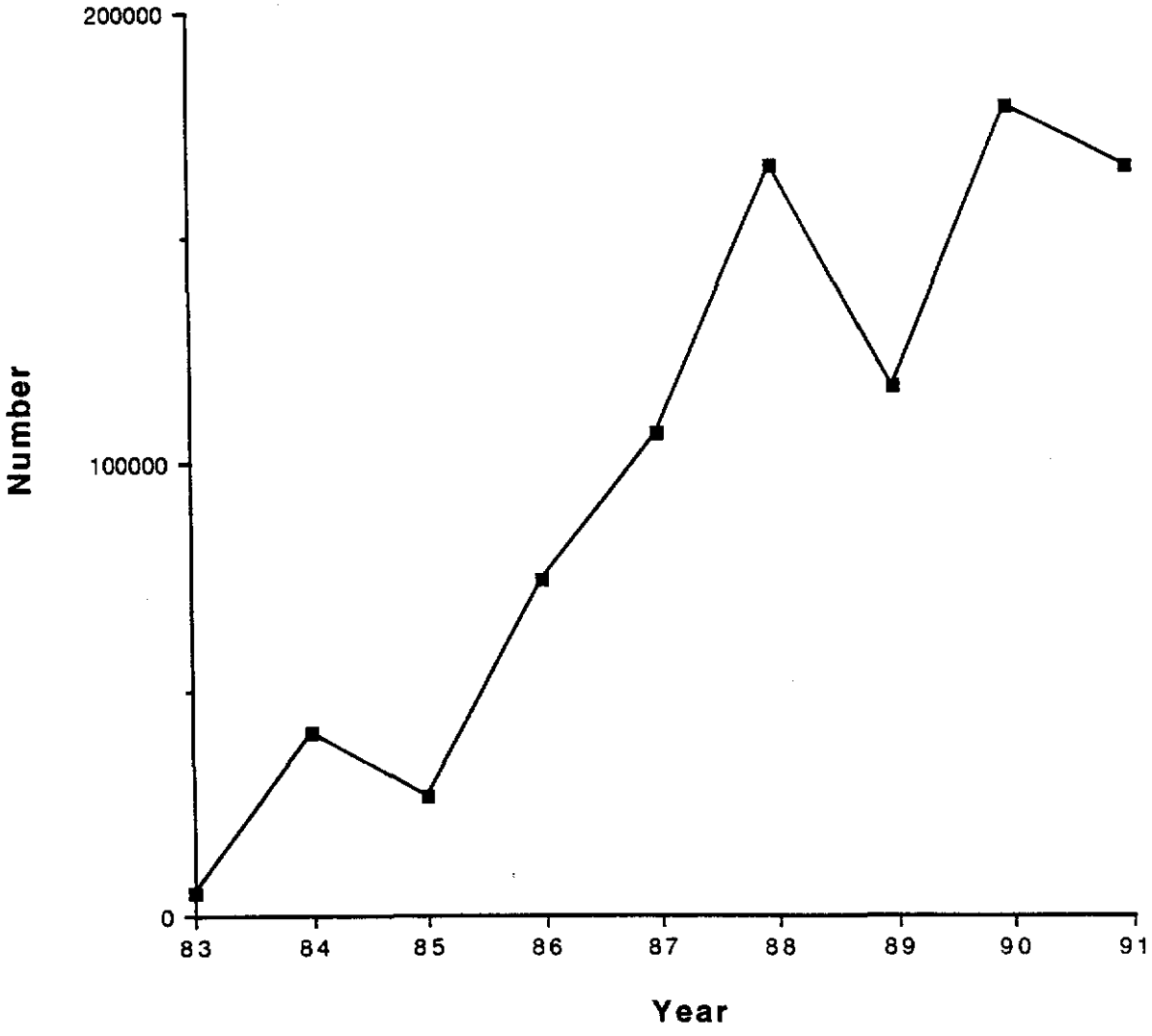

Figure 4. Hatchery-reared trout released into Loch Leven, 1983-1991.

1974a). The stock of trout beginning their third or more years in the loch in April, was estimated to have fallen from 126 665 in 1968 to 52 337 in 1971 (Thorpe, 1974b). Since the IBP studies, there have been electro-fishing surveys of some of the feeder streams and a sample of pre-spawning fish caught at the hatchery in November 1991 (A. Walker, SOAFD, pers comm). However, there has been no further work on the loch itself and the population dynamics of current trout and perch populations is unknown.

4. CORMORANT COUNTS

The cormorant breeds almost exclusively in coastal colonies where birds can be found at any time from the end of March to mid-September with eggs being laid in late April or early May or even later in north Scotland (Sharrock, 1976). In Scotland, most of the population breeds north of the Great Glen, particularly on western and northern coasts and islands. There are few colonies on the east coasts of Scotland, England and Ireland. By contrast, winter records are distributed more or less evenly around all coasts and many others are from inland waters. Both adults and immature birds disperse widely with individuals being recorded up to 65 km from the sea (Dunnet, in Lack 1986).

4.1 National Population Trends

The winter population of cormorants was counted in 1985 (organised by the BTO) but the results are not yet available. However, Lloyd *et al.* (1991) recently reviewed the status of breeding seabirds in Britain and Ireland. A total of 10 400 pairs of breeding cormorants were counted on the coasts of Britain and Ireland in 1985-87, compared with 8000 pairs in 1969/1970. No estimates of the accuracy of such counts was given. Scotland was the only part of the UK where cormorant numbers have apparently declined, from 3400 pairs to 2900 pairs between the two surveys. The pattern of change was different between the east coast and the north and west. On northern, north western and south western coasts, numbers fell by 14%, 36% and 7% respectively, whilst on the east coast numbers increased by 175% overall. In the south east (Dunfermline, East Lothian, Berwickshire), numbers increased from 153 to 406 pairs whilst in the north east (Moray, Aberdeen, Kincardine and Deeside), they increased from 1 to 18 pairs. On the east coast of Caithness numbers declined from over 825 pairs to only 268. The only detailed surveys of breeding cormorants on the east coast have been carried out in the Firth of Forth, here the breeding population has remained relatively stable at 210 - 240 nests between 1966-1986 (Harris *et al.*, 1987). Unfortunately, more recent data are not available. Although there is no evidence that Scottish cormorant numbers have increased dramatically in recent years, it is possible that they might have done so locally, perhaps on the Firths of Tay and Forth, and trends in the winter population are unknown.

4.2 Loch Leven Counts

Since 1981, cormorants have been counted on Loch Leven between September and March (Fig. 5). Between the winters of 1981-82 and 1987-88 mean numbers fluctuated

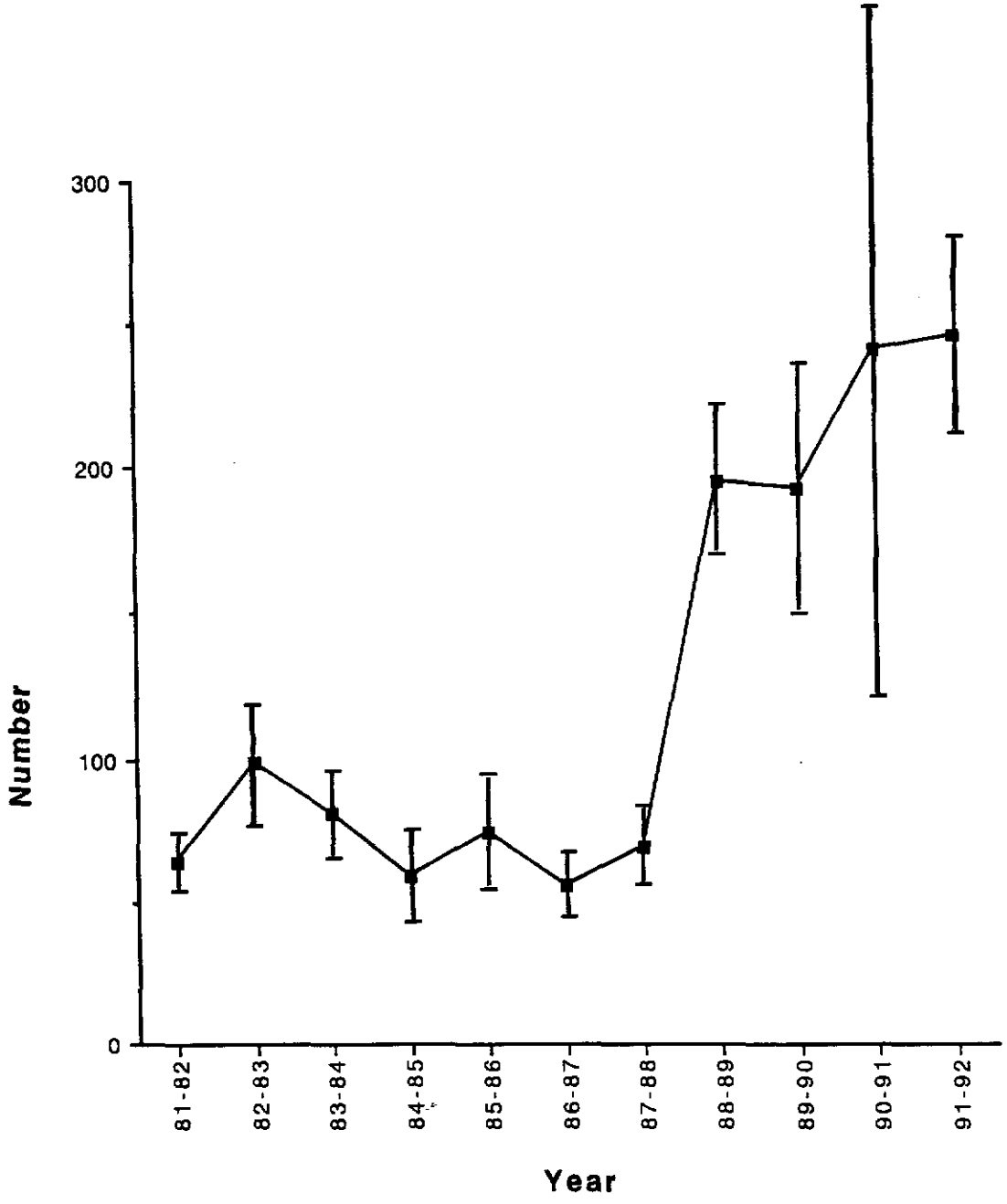

Figure 5. Mean winter cormorant counts at Loch Leven, 1981-1992. Figure shows means of Sept-March counts, bars represent std. errors.

between 50-100 birds whilst in the following winters numbers increased dramatically to between 193 - 246 birds, seasonal trends in numbers are also apparent from counts (Fig. 6). Prior to the autumn 1988 increase, numbers remained fairly constant throughout the winter, however, in recent years, numbers have increased throughout the winter to a maximum in February before declining to mid-winter levels in March. Numbers continued to decline and by May about 20 birds are present, there is sometimes a slight increase in late summer but the main influx of birds begins in September. Counts in spring (Jan-March) are usually higher than those in autumn (Sept-Dec), a phenomenon which has become perhaps more pronounced since the autumn 1988 increase (Fig. 7).

4.3 Counts Elsewhere

Cormorants have been recorded during national wildfowl counts from the 1986/87 winter onwards, though not always so. As a result there are many missing values and the counts cannot be relied upon to show an accurate picture of either numbers or distribution. Nevertheless, frequent counts from three sites in Perth and Kinross District show that numbers tended to reach a peak in October/November at freshwater sites (Loch of Clunie and Drummond Pond) and in December-February at an estuarine site (Perth tree roost). Furthermore, between 1988-1991, there has been a three-fold increase in the maximum spring counts at the Perth tree roost and a similar increase in the maximum autumn counts at Loch of Clunie (Appendix 1).

The seasonal trends in cormorant numbers at Loch Leven might be accounted for by local birds moving there in late winter although this seems unlikely because relatively few birds were counted elsewhere. The increase in cormorants at Loch Leven since 1988 is of the same order as that recorded on other freshwaters and the Tay estuary suggesting that there has been an overall increase in cormorant numbers in Perth and Kinross.

5. CORMORANTS AT OTHER FISHERIES

Managers of some nearby standing freshwaters were contacted and asked for their perceptions of current cormorant numbers and whether or not cormorants were viewed as a problem. Replies were as follows.

5.1 Loch Fitty, Dunfermline

There are now many more cormorants than 8 - 9 years ago. Birds are present in small numbers (ca. 12) during the summer but increase from September onwards peaking from late February to mid-May. Birds fly in each morning from the direction of the Forth and up to 140 have been recorded on the loch. The birds are regarded as a problem because they are thought to eat so many trout as to detract from the fishery harvest.

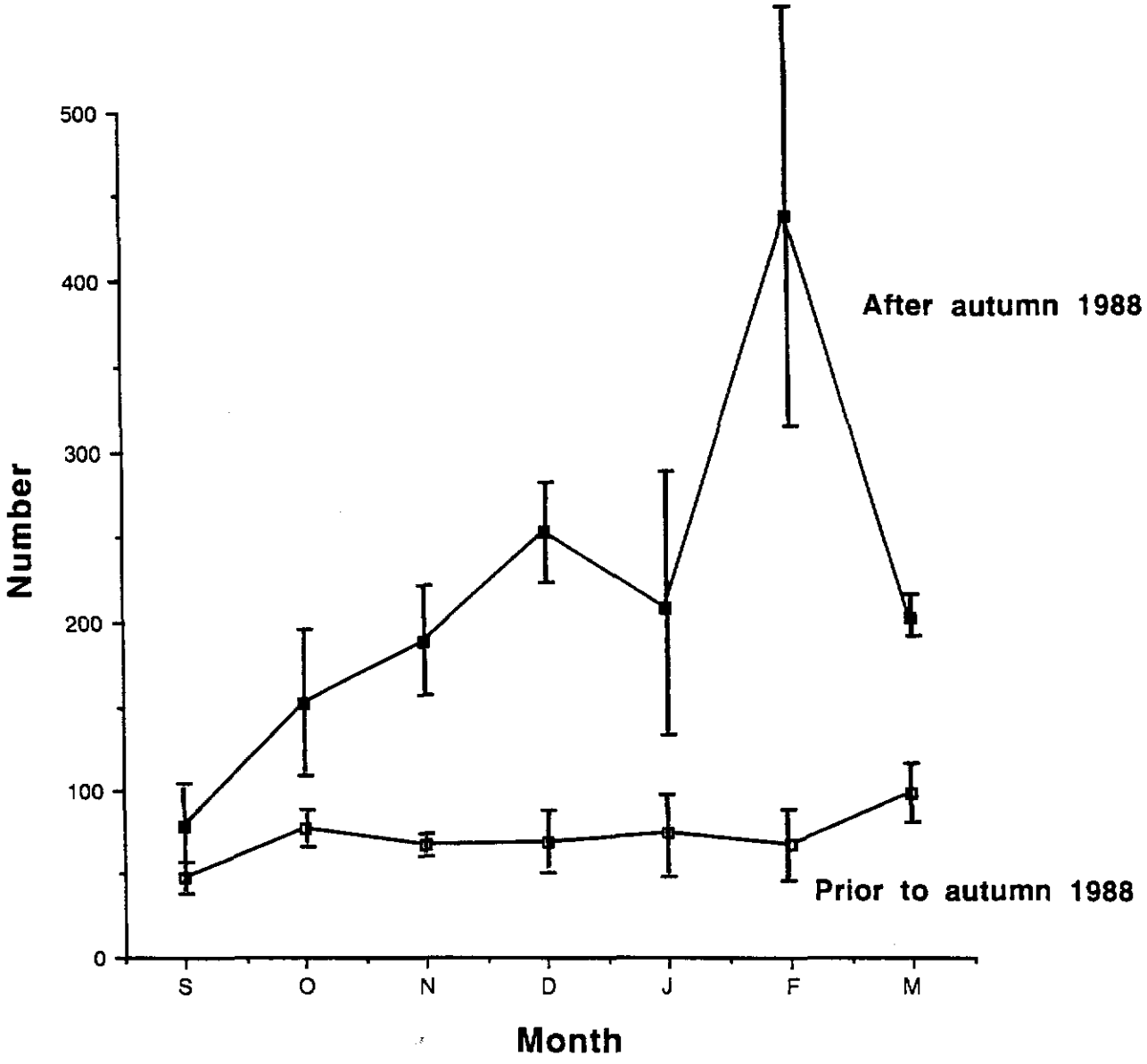

Figure 6. Mean monthly counts of cormorants at Loch Leven prior to autumn 1988, and thereafter. Bars represent std. errors

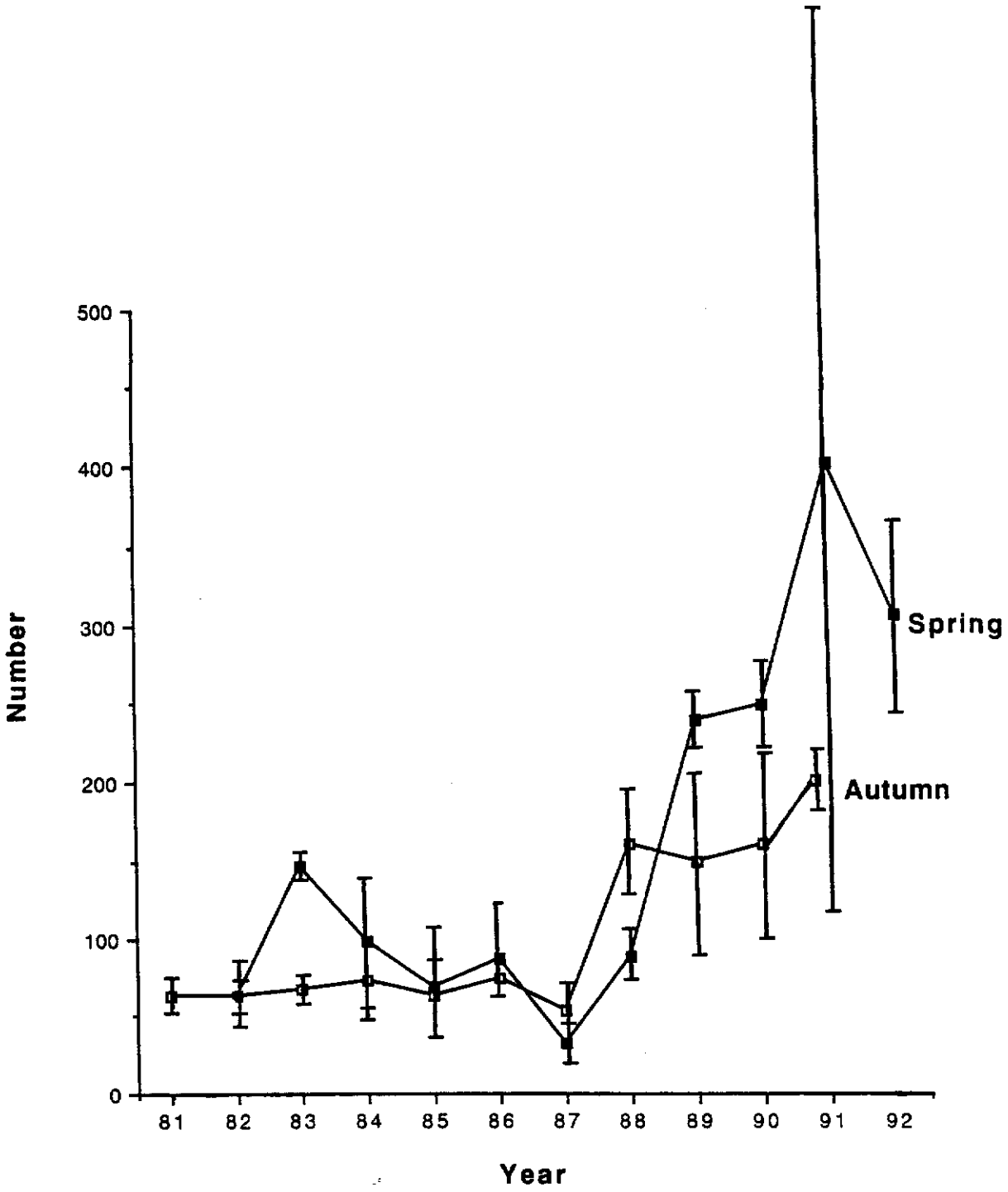

Figure 7. Mean autumn and spring cormorant counts at Loch Leven, 1981-1992. Bars represent std. errors.

5.2 Craigluscar Reservoir, Dunfermline

Birds are most frequently seen on the reservoir during March, April and May, although the loch is seldom visited by anglers or bailiffs in the winter and birds may be visiting then. Birds fly in from the direction of the Forth in the morning and, although numbers are small (no more than 6), they are regarded as a problem as they damage fish. Birds often leave the reservoir in the direction of Lochs Fitty and Leven.

5.3 Stenhouse Reservoir, Dunfermline

Cormorants have increased in recent years with up to 17 recorded in spring 1992. This year the reservoir was visited daily and the cormorants scared off. Few, if any, birds are present in the summer but numbers increase in autumn and spring or at other times if poor wether forces them to move from the coast.

5.4 Clatto Reservoir, Fife

Cormorants are present but any potential problems are under control. During the last two seasons there has been granted a licence to shoot birds. One was shot in 1991 but none this year. Shooting is viewed primarily as a scaring measure, rather than an attempt to reduce numbers, and is apparently successful. Numbers on adjacent waters are said to have increased as a result.

5.5 Cameron Reservoir, Fife

Cormorant numbers have increased in recent years. Maximum numbers have reached 10-12. Visits are seasonal, mainly October-April, and appear to be related to the severity of weather on the coast.

5.6 Loch Ore

Cormorant numbers in the spring have increased markedly in the last 2 to 3 years. Maximum numbers have reached about 60. A few birds are present in late February and early March but the main influx occurs in March/early April. By late April, numbers are decreasing and only 1 or 2 birds are recorded in the summer. There does not appear to be an increase in the autumn. Fish used to be stocked in large quantities in late February/early March but now a few hundred are released each week and there has been an associated decline in cormorant numbers with a maximum of about 30 birds recorded last year. Birds are scared but not shot.

5.7 Beecraigs Loch, Lothian

Cormorants have not been a problem over the last 11 years, although occasional birds are present in the winter.

5.8 Bowden Springs, Lothian

Cormorant problems arose two years ago when fish cages were introduced to the loch. Single birds visited every day and damaged fish in cages. Single birds still visit irregularly, particularly in February, March and April when weather in the Firth of Forth is poor.

5.9 The Association of Scottish Stillwater Fisheries

The Association is certainly concerned about the problems of cormorants and stillwater fisheries. Its members throughout Scotland perceive a similar pattern with cormorants, apparently increasing over the last 5 to 6 years and dispersing more widely. The Association has contacted the Scottish Office Agriculture and Fisheries Department on several occasions with respect to its licensing policy for shooting birds on the large number of waters where they are becoming a major problem.

6. THE AGE STRUCTURE AND BIOMETRICS OF THE CORMORANTS AT LOCH LEVEN

The age of cormorants can be determined by plumage characteristics (Alstrom 1985); adult birds (those of three calender years or older) have dark blue-green breasts, whilst those of younger birds (immatures) have varying amounts of white feathers. Comparisons could be made between a 1972-1977 sample and those shot in the spring of 1992 (see section 8 for sample details). Juvenile birds are generally considered to be more vulnerable to shooting than older ones (eg van Vessem *et al.*, 1985) and so a shot sample may not be representative of the true age ratio of the population. Nevertheless, bias is likely to be constant and the two samples are significantly different ($\chi^2 = 9.01$, df = 1, $P < 0.01$). A higher than expected proportion of birds in the earlier sample were immature; more of the 1992 birds were adult, suggesting that the proportion of adults at Loch Leven has increased. Indeed the 1992 sample contained a higher proportion of adults than previously recorded from shot samples elsewhere in Scotland (eg 29% in freshwaters in south-east Scotland, 1991-1992, n = 49, and 27% on the Scottish west coast, 1985-1987, n = 56, Marquiss & Carss unpublished data).

The native cormorant species in the UK is *P. carbo* which breeds in north west Europe whilst a slightly smaller subspecies, *P.c. sinensis* breeds in central and southern Europe. Although it may be possible to distinguish the two subspecies on the basis of plumage, biometric measurements are probably more reliable (eg Cramp & Simmons, 1977). The sample of 20 birds shot in spring 1992 were measured (Table 1). Most were well within

TABLE 1. Cormorant beak depth (mm). Ranges for *P. carbo* and *P. sinensis* (Cramp & Simmons, 1977) and range for Loch Leven, Spring 1992.

P. carbo	*P. sinensis*	Loch Leven
13-18	11-16	12.1-16.8

the size range of *P. carbo* but one individual was smaller. This bird could well have been *P. sinensis* and of continental origin.

7. THE DIET OF CORMORANTS AT LOCH LEVEN

Three different data sets relating to cormorant diet at Loch Leven were available during the current study.

(1) Stomach contents of birds shot between 1971-77 recorded by A. Allison (NCC unpubl data). Data include date of death, age class and length estimates (in inches) of either intact or partially digested fishes (Appendix 2). Well-digested material was presumably excluded. For analysis, length estimates were converted to metric measurements and published length; weight relationships (trout - Clelland 1979; perch - Craig 1974) were used to calculate the weight of ingested fishes. Trout and perch were the only species of fish recorded in stomachs, and their proportions in the diet in terms of both numbers and biomass were calculated (Table 2, Fig. 8). Four trout and 3 perch were not measured and therefore no weight estimates were available. In each year perch dominated the diet numerically. However, many of these fish were small and only in 1972, 1974 and 1977 were perch the dominant species in terms of mass. Nevertheless, in each year perch accounted for at least 25% of the diet by mass. Over the 6-year period, perch dominated the diet of cormorants both numerically (n = 184, 88.5%) and in terms of mass (wt = 5550 g, 54.6%).

(2) Stomach contents of birds shot between 1981-1992 (NCC, unpubl. data). Data include the numbers shot, the numbers examined, the number with empty stomachs and the numbers containing either trout, perch or three-spined stickleback (*Gasterosteus aculeatus*) (Table 3). It was unlikely that every stomach contained only fish of one species. Nevertheless, the crude categorisation effectively shows that the proportion of stomachs containing perch has declined whilst that of stomachs containing trout has increased and only since 1989/90 have three-spined sticklebacks been recorded in the diet (Fig. 9).

(3) Stomach contents of birds shot in the spring of 1992 (19 January - 7 March) and examined specifically for this report (for full details see Appendix 3). From a total of 20 birds examined, only 15 contained food (Table 4, Fig. 10). The length, and hence weight, of one trout could not be estimated. Nevertheless, the diet was dominated, both numerically and in terms of mass, by trout.

Although the nature of these three data sets necessitates each being analysed and interpreted differently, there appears to have been a change in cormorant diet at Loch Leven over the last 20 years. For analysis, stomachs containing fish were categorised as containing either trout or perch and samples were split into three 6-year periods (Table 5). Over the study period the proportion of stomachs containing trout have increased significantly whilst those containing perch have decreased ($\chi^2 = 199.9$, df = 2, $P < 0.001$). In the 1970s, perch were a very important part of the diet. However, during the 1980s fewer were recorded, and trout were more important with the spring 1992 sample being dominated by them.

TABLE 2. Cormorant diet at Loch Leven, 1972-1977 in terms of number and weight of fishes recorded.

	1972		1973		1974		1975		1976		1977		1972-77	
	No	Wt(g)	No	Wt(g)	No	Wt(g)	No	Wt(g)	No	Wt(g)	No	Wt(g)	No	Wt(g)
Trout	4	657	6	1152	0	-	6	1806	6	818	2	180	24	4613
Perch	9	1460	9	842	3	446	33	442	116	737	14	1623	184	5550
Total	13	2117	15	1994	3	446	39	2248	122	1555	16	1803	208	10163

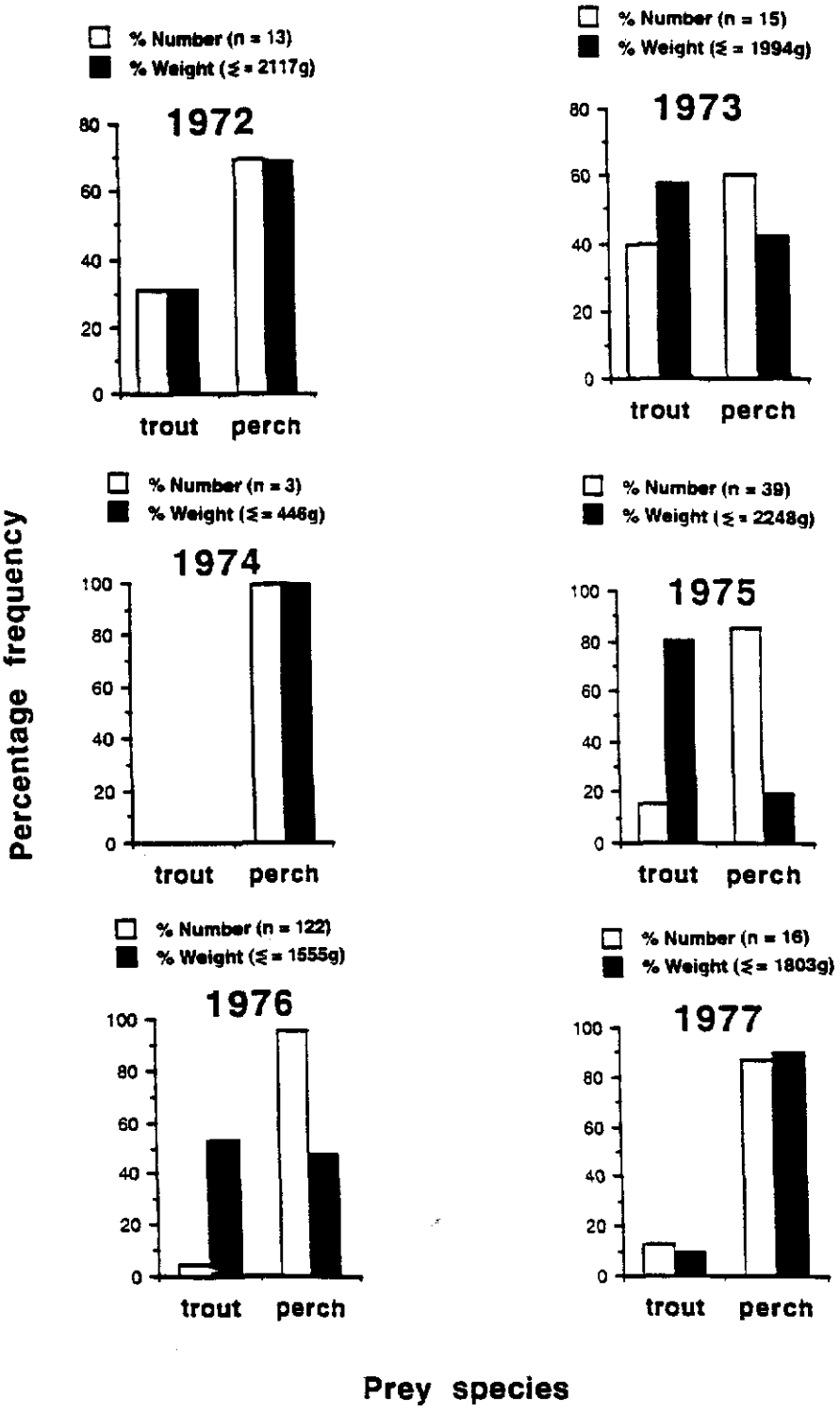

Figure 8. Cormorant diet at Loch Leven, 1972-1977. Data from Table 1.

TABLE 3. Cormorant Diet at Loch Leven, 1981-1991/92

	No. shot	No. examined	No. empty	No. containing Trout	Perch	3 Sp. S'back
1981	108	80	0	26	54	0
1982	52	48	6	14	28	0
1983	40	32	4	20	8	0
1984	61	54	21	18	15	0
1985/86	49	40	3	27	10	0
1886/87	52	42	0	37	5	0
1987/88	76	53	10	23	20	0
1988/89	206	135	23	94	18	0
1989/90	304	187	11	106	21	49
1991/92	332	178	12	131	11	24

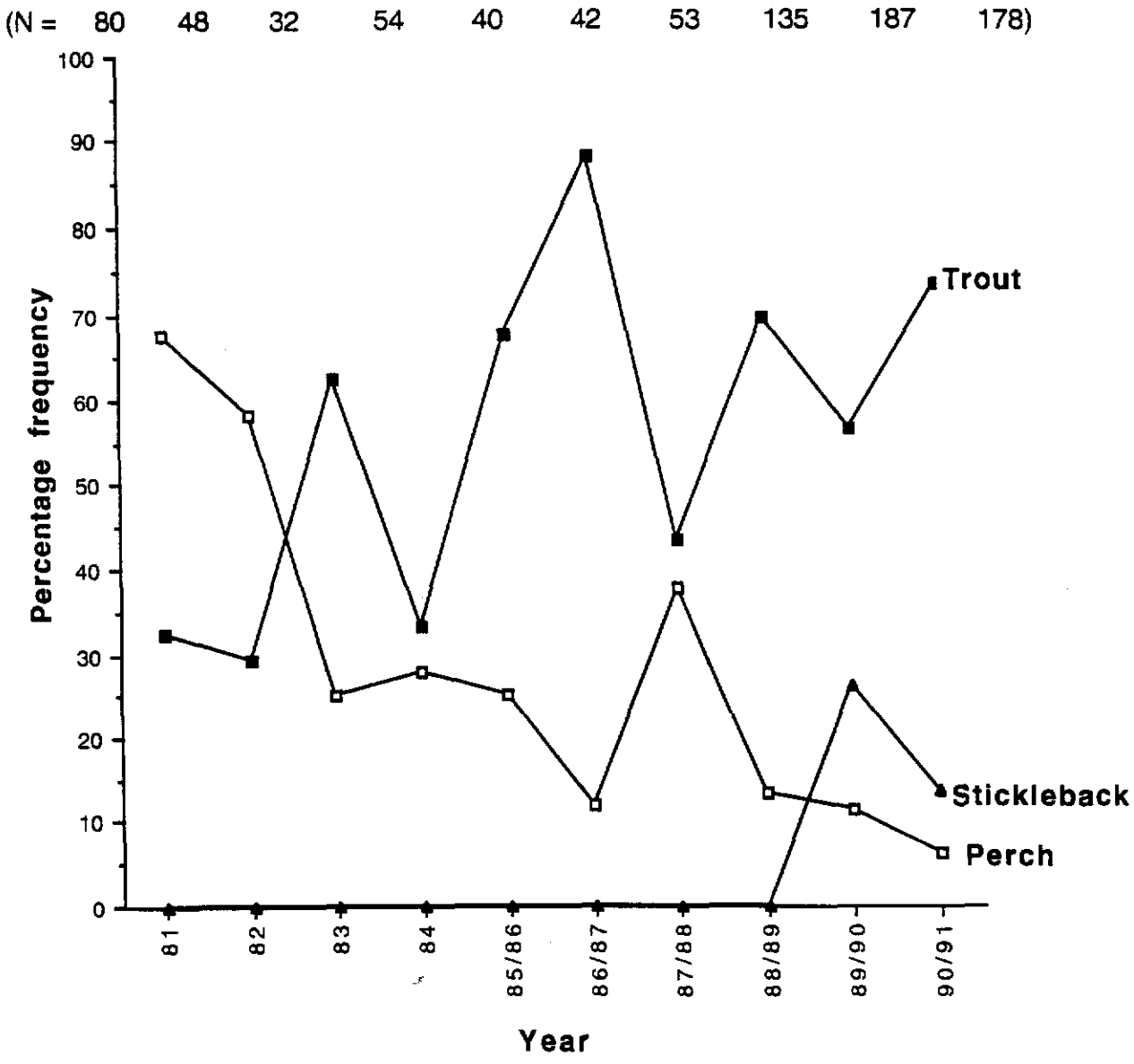

Figure 9. Cormorant diet at Loch Leven, 1981-1990/91, in terms of proportions of stomachs containing either trout, perch or stickleback. Data from table 3. N = number of stomachs.

TABLE 4. Cormorant diet at Loch Leven, Spring 1992 by number and weight, of fishes recorded. 20 stomachs, 5 empty, data from 15 birds. One trout was not measured and so was not included in the total weight.

	N	%	Wt	%
Trout	19	67.9	4669	96.6
Perch	3	10.7	162	3.4
3 Sp. S'back	6	21.4	3	0.1
Totals	28	100	4834	100

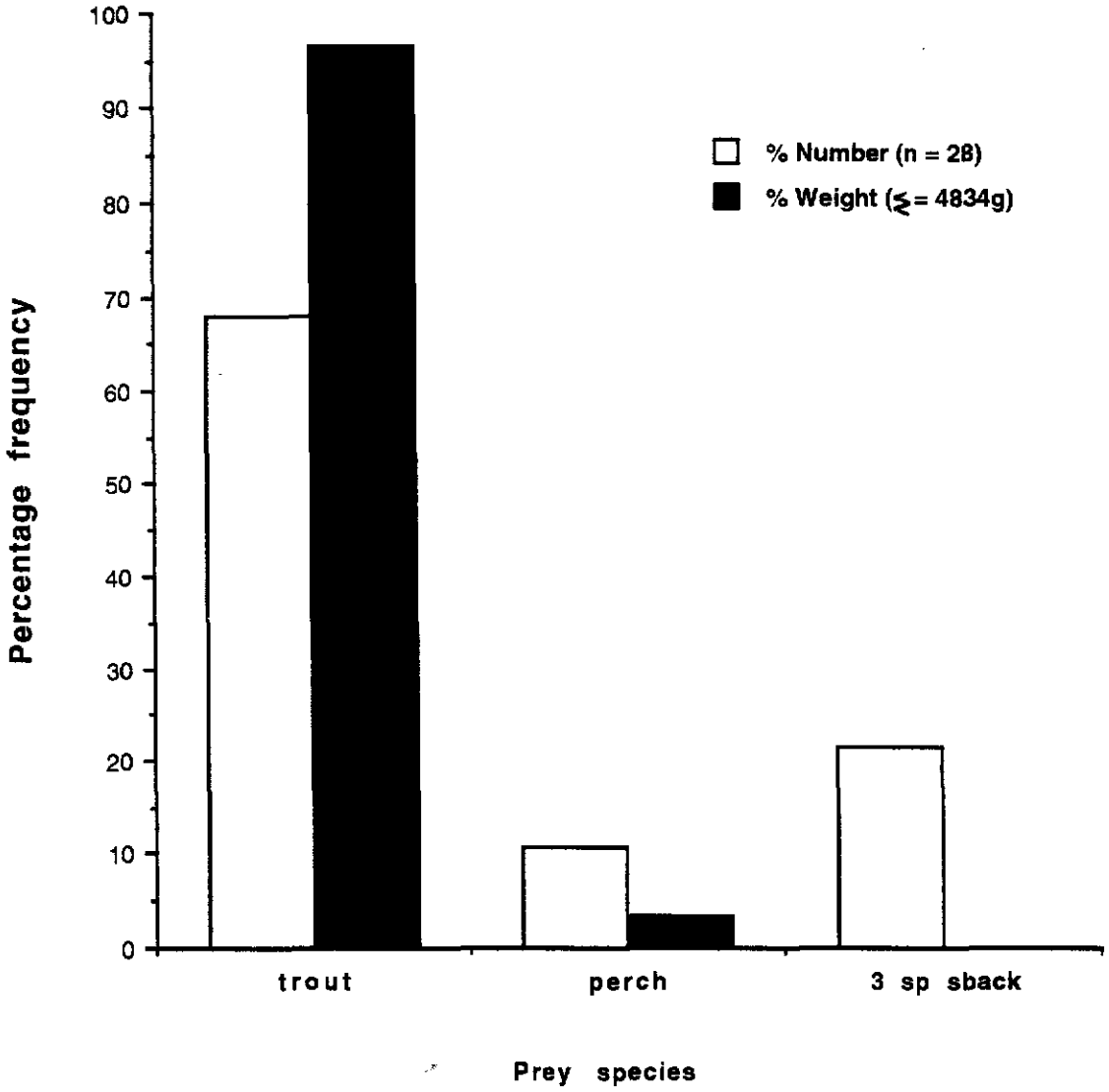

Figure 10. Cormorant diet at Loch Leven, spring 1992. Data from Table 3.

TABLE 5. Percentage of cormorant stomachs containing either trout or perch in 3 periods; 1972-77, 1981-86, 1987-92.

	No. stomachs containing food	Percentage of stomachs containing	
		Trout	Perch
1972-1977	67	30	70
1981-1986	262	54	46
1987-1992	368	84	16

8. THE SIZE OF TROUT TAKEN BY CORMORANTS

It could be expected that in recent years cormorants have been preying upon the large numbers of relatively small hatchery-reared trout released into the loch. However, length estimates for trout eaten during 1972-1977, as determined by direct measurements, and for the 1992 sample, as determined by measurement of atlas vertebrae (Feltham & Marquiss, 1989), can be compared. There was no difference in the sizes of trout taken by cormorants in the two samples, both had a median length of 25 cm, (Mann-Whitney U-test, W = 335, NS); (Fig. 11). In 1992, about half the trout taken by cormorants were large enough to have been kept by anglers (ie over c. 9ins. 23 cm), the remainder were below takeable size.

9. METHODS OF DETERRING CORMORANTS FROM FISHERIES

There are several reviews of methods of deterring fish-eating birds from fisheries (eg Carss & Marquiss, in press; Moerbeek *et al.*, 1987; Draulans, 1987; EIFAC, 1989). The latter also deals with bird predation at open water systems and the control of bird-related problems is discussed in detail and summarised below.

9.1 Shooting

Although in general shooting cormorants requires a licence, for many it is an appealing form of control - an immediate and apparently effective response to a perceived problem. However, numerous studies have shown that the efficacy of shooting is dubious; either effective for only a short time or (more often) totally ineffective.

9.2 Other lethal methods

Other methods such as trapping, poisoning and capture/release have all been tried, with similar results to shooting.

9.3 Scaring devices

Scaring devices have been used with mixed success. Audio deterrents include loud noises, gun shots, humlines, acoustic gas cannons, fireworks, taped human voices and bird distress or alarm calls. Several studies have shown that loud noises are at best only temporarily effective. Visual deterrents including foil and cloth strips, flags, balloons, flashing lights, model aircraft, scarecrows and model raptors have been used, again with variable results. Cormorants appear to be less susceptible to such deterrents than for example gulls. Water spray systems have proved particularly effective against gulls roosting on reservoirs in North America but may be ineffective on feeding cormorants. Large flocks of (unspecified) birds appear to return more quickly after disturbance than smaller ones.

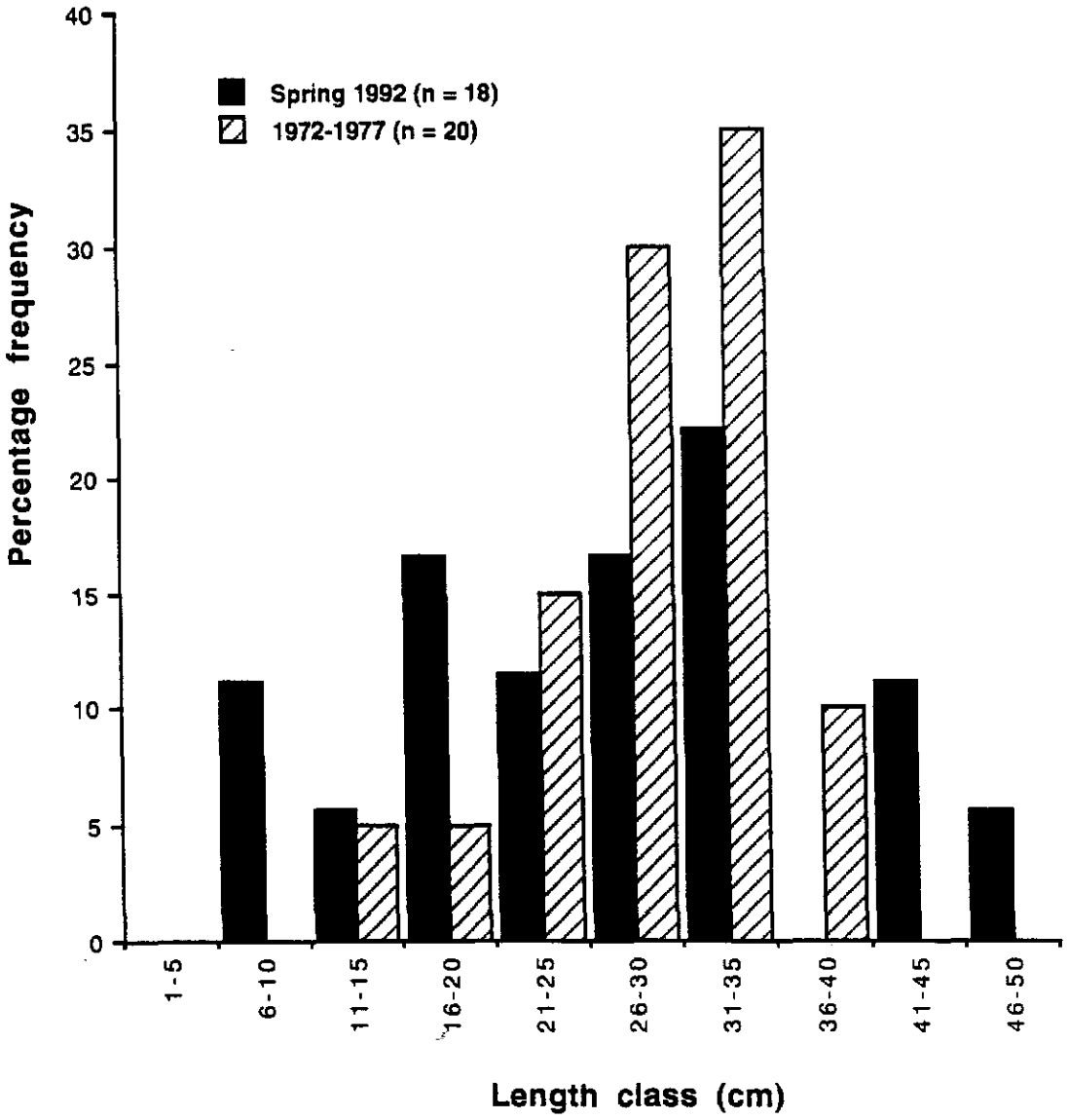

Figure 11. Length frequencies of trout consumed by cormorants at Loch Leven, 1972-1977 and Spring 1992.

9.4 Exclosure devices (overhead nets, wires and lines)

Partial exclosure using overhead wires or lines is much more practicable than complete exclosure on large ponds or open waters. Wire, braided, mono- and multi-filament man-made fibres are commonly used. Moerbeek *et al.* (1987) experimented with several methods of deterring cormorants from visiting fish farm ponds up to 10 - 11 ha in area. Lines across the ponds deterred large groups from landing but single birds landed with little hesitation. The result was prolonged predation at a much lower intensity and the amount of damage was probably unchanged. Twenty metre spacings between lines were as effective as 10 m spacings in deterring birds and a height of 40 - 60 cm above the water surface was recommended.

9.5 Buffer populations

In theory, valuable stock may be made less vulnerable by the introduction of a buffer prey stock, either by mixing smaller fishes with more valuable ones or introducing a low-value, easily caught species. This was apparently effective in Australian fish dams (Barlow & Bock, 1984).

9.6 Conclusion

It is obvious that there is no deterrent system which could be implemented at Loch Leven with much chance of success. This is a problem common to almost all open water systems where preventative measures to control damage by birds appear to be neither practicable nor effective (EIFAC, 1989). However, buffer populations of low-value fish (eg perch) may be appropriate.

10. CORMORANTS AND STOCKING PRACTICES

Reductions in stocking density of fish, although not always practicable, can reduce the incidence of predation. Barlow & Bock (1984) found that small ponds stocked with few fish (ca 150 per ha) were less commonly visited by cormorants than those with a higher stocking density (ca 450 per ha). Changes in the timing of stocking may also be effective, for instance Moerbeek *et al.* (1987) found that late stocking of carp fry meant that fish were vulnerable to attack for a shorter period and that fewer birds visited the farm later in the season. In the UK, the susceptibility of over-wintering brown trout has been recognised in the stocking strategy at Rutland Water, Leicestershire. Here, angling capture rates of autumn-stocked 1+ trout declined from over 30% to less than 5% between 1982-85 when the wintering cormorant population increased from 75 to 250 birds. Subsequently, trout have been stocked in Rutland Water only in the spring and summer (Pawson, 1991) but no data are given for subsequent capture rates.

11. DISCUSSION

Cormorant predation at managed fisheries is a worldwide problem. In Australia many fish species are farmed in dams, a form of extensive aquaculture where hatchery-reared fish are released in small ponds for recreational angling and domestic consumption. Three species of cormorant, including *P carbo*, regularly visit such dams and up to 50% of the fish may be consumed by them (Barlow & Bock, 1984). In the United States the double-crested cormorant (*P. auritus*) is considered to be one of the biggest threats to the catfish farming industry, with current losses estimated to be $3 million per year (Broadway, 1989). Little is known about the impact of cormorants on stillwater fish populations in the UK (Feare, 1988). Cormorants are now protected legally in many European countries and their numbers there have increased dramatically (EIFAC, 1989). Such was the concern about this increase that the Food and Agriculture Organisation of the United Nations commissioned the European Inland Fisheries Advisory Commission (EIFAC) Working Party to investigate bird predation.

The Commission concluded that in most regions, fish-eating bird damage in open waters was mainly of local interest and generally not considered to be of great economic importance. However, this was not the case in areas where cormorant numbers have increased nationally. Here, predation at many pond farms had increased to such a level that farmers became bankrupt and ceased operating. Problems were also increasing on open waters. Bearing this in mind, the situation at Loch Leven cannot be ignored.

Two questions need to be addressed. Does the current level of cormorant predation on Loch Leven trout represent a significant economic loss to the fishery, and, if so, can such losses be prevented?

(1) Is the current predation by cormorants resulting in economic loss?

Wintering-cormorant numbers at Loch Leven have increased three-fold in the past decade. This increase was not gradual but occurred between the 1987/1988 winter and the following one. The diet of cormorants at the loch in the spring of 1992 was mainly trout, about half of which were large enough to be taken by anglers. Rough calculations involving the mean weight of trout eaten, the mean weight of cormorants, an estimate of their daily food requirements (20 - 25% body weight) and count over the 1991-1992 winter suggest that there could be a significant loss to the trout population of the order of several thousand fish. However, this loss has certainly not been established. It is impossible to calculate the impacts of cormorants when the size of the trout population is unknown. Even if we had an accurate estimate of the trout numbers we would also need to know how the population responds to the removal of fish. It is possible that as fish are removed the remaining fish might have an improved growth. Thus whilst cormorant predation could have some impact on the size and structure of the trout population without further study we cannot estimate the extent of this impact.

Furthermore, changes in the size and structure of the trout population might not necessarily lead to changes in the economics of the fishery, which depends on catches.

Low catches might be the result of a reduced trout population but might also be the result of changing trout feeding patterns.

A pattern of decreasing catches with increasing cormorant numbers could provide circumstantial evidence for an effect of cormorants on the fishery. Trout catches at Loch Leven have dropped over the last two seasons (from a record catch in 1980) but this decline is not clearly associated with the increase in cormorants, nor is it unprecedented. Annual catches have fallen to less than 10 000 four times (1971, 1981, 1983, 1991) in the last twenty-two years, three of these occurring before the increase in cormorants. Clearly, factors other than cormorant predation were involved in low catches, at least in the earlier years.

In conclusion, there is ample evidence from the numbers and diet of cormorants at Loch Leven that they could have an impact on the fishery but that this is far from established, particularly in view of the lack of close correspondence between increasing cormorants and low catches.

(2) If cormorant predation does cause economic loss to the fishery, can it be prevented?

Cormorant predation of Loch Leven trout could only be reduced numerically, by reducing the numbers of cormorants using the loch, or reducing the proportion of trout in their diet. Reducing the numbers of cormorants using the loch seems impractical because exclosures and deterrents are impractical on such a large water body and shooting is apparently ineffective.

Numbers

Shooting is probably inaffective because the birds using the loch are drawn from a very large and probably increasing population. The seasonal pattern of cormorant counts elsewhere in Perth and Kinross does not correspond to that at Loch Leven so the late winter/early spring increase at the loch could conceivably be as a result of local birds from elsewhere concentrating there. However, this seems unlikely as the local counts never reach the numbers recorded on Loch Leven.

Cormorant numbers are increasing throughout much of Europe, including the United Kingdom. Although their numbers have decreased in Scotland as a whole, they have increased on the Northern Isles and on the east coast (Lloyd *et al.*, 1991).

After breeding, cormorants disperse widely from their colonies and are equally at home in freshwater, brackish or saltwater habitats. Birds breeding in Shetland rarely reach the mainland whilst those from Orkney do regularly (Dunnet, in Lack, 1986). Young birds from Orkney move south, reaching Caithness in August and the Forth in September whilst older birds arrive slightly later; birds from the Farne Islands also winter in the Forth (Dunnet, in Lack, 1986; Thom, 1986). Ringing recoveries show that birds from different breeding areas had different patterns of dispersal, with those from northern

and eastern Britain dispersing along eastern coasts rather than crossing over open water to the east, or land to the west (Coulson & Brazendale, 1968). There are, therefore, likely to be considerable numbers of cormorants moving up and down the east coast during the winter.

The UK winter population is thought to be mainly native (Dunnet, in Lack, 1986). However, one of the birds examined from the spring 1992 sample at Loch Leven was smaller than published measurements for the nominate race (*P. carbo*) and did fall within the range for *P.c. sinensis*. Perhaps some of the birds visiting Loch Leven in the winter are of continental origin, but further investigations are needed to confirm this. Irrespective of the precise provenance of Cormorants wintering at Loch Leven, it seems they are drawn from a large population so shooting even larger numbers will not drastically reduce the numbers of cormorants using the Loch.

It is possible that fewer cormorants might use the loch if fish availability were reduced at critical times of year. Cormorant predation on over-wintering trout has been reduced at some put-and-take fisheries by 'fishing down' their numbers towards the end of the angling season and stocking only in spring and summer (Pawson, 1991). Stocking during this period means that fish are introduced to a water at a time when cormorant numbers are low, or declining, and also gives them the longest period to acclimatise before birds arrive again in the autumn. However, Loch Leven is not a put-and-take fishery and, although large numbers of hatchery-reared trout have been released in recent years, there is also likely to be substantial natural breeding. The fate of the hatchery-reared fish and their impact on the 'wild bred' population is unknown. Hatchery-reared fish are not marked in any way before release and it is impossible to determine what proportion of either the anglers catches or the cormorants diet they constitute. Stomach contents from spring 1992 contained few small trout suggesting that cormorants are not eating large numbers of recently released fish. However, the provenance of the larger fish was unknown.

Diet

It seems that there is little likelihood of reducing the cormorant use of Loch Leven by reducing the overall population, by exclosure, by deterrent, or even by reducing trout availability (though see later). The remaining alternative is to reduce the proportion of trout in their diet by increasing the availability of perch.

Loch Leven is internationally renowned for its trout fishery, however, Thorpe (1974a) found that in terms of biological production, perch dominated the fish population of the loch. Tentative estimates of annual production for the two species were 2.2 - 3.9 gm^{-2} for trout and 5.1 - 67.4 gm^{-2} for perch, however, the latter estimates included the production of juveniles whilst juvenile trout production, confined to feeder tributaries, was not included. Nevertheless, perch populations in the early 1970s were large and the species dominated the diet of cormorants at the loch.

Long-term studies of perch population dynamics (eg Craig, 1980; McCormack, 1965) have shown that populations are very flexible, respond quickly to environmental

changes and are often dominated by particularly strong year-classes (cohorts). Furthermore, perch populations throughout much of the UK were severely reduced around 1976 by an outbreak of disease (Craig *et al.* 1979). There is anecdotal evidence (W. Wilson pers comm) that perch populations have declined at Loch Leven since the 1970s and the species is certainly no longer common in the diet of cormorants there. Research is needed to estimate current perch populations in the loch. Management practices which benefit the perch population could help to reduce predation levels on trout but the introduction, or enhancement, of a fish species to act as a buffer prey species has not been attempted in open waters. Natural perch populations are also likely to fluctuate in response to environmental conditions and a programme of restocking may be ineffective if current conditions for their survival are poor.

12 AREAS REQUIRING FURTHER STUDY

12.1 Modelling

Since we can't reduce cormorant predation experimentally under 'controlled' conditions, establishing the impact of cormorants on the fishery requires detailed modelling of the effects of cormorants removing trout on anglers' catches. Data required are the numbers of cormorants feeding, the composition of their diet, the size of the trout population and its structure, the dynamics of the trout population including the relationship between population and capture-rate by anglers.

12.2 Trial and error

An alternative approach is by trial and error using various management techniques, for example:

(a) *Reducing stocking.* It is possible that the very high stocking rates have been involved in the increasing use of the loch by cormorants either by providing an abundance of naive fish, or in the decline of the birds alternative prey (perch) through, for example, dietary competition. Were this so, reducing stocking levels might reduce cormorant predation on trout so that for a lower stocking effort the rod-caught returns might be enhanced - a more cost-beneficial management strategy.

(b) *Stocking at varying times of year.* Stocking the loch with fish at times of year when the cormorant population is reducing (April onwards) might give the novel population of fish a chance to adapt and stabilize in the presence of few cormorants and well before they start returning in October.

(c) *Stocking with perch.* Perch populations can fluctuate dramatically and in times of perch shortage, cormorants at Loch Leven are bound to take more trout. Maintaining a consistently high perch population (if possible) might avoid this.

Only one novel management regime should be carried out at any one time and cormorant numbers and diet should be monitored closely together with catch statistics.

12.3 Conclusions

There are advantages and disadvantages of both approaches. Modelling will result in an inevitable overall gain in knowledge which would aid fishery management, but on the other hand might not solve the problems of low catches in the short term. Modelling requires quite precise data which can be expensive to collect.

In contrast, the management trials might result in higher catches relatively quickly but because these are not 'controlled' experiments, they would provide little hard evidence of the mechanisms involved. Moreover, 'trial and error' management is inherently risky - several years of trial might not produce a result satisfactory to the fishery.

Perhaps a third option might be to monitor trout and cormorants in a less detailed fashion as one or other of the management trials is in progress. An important aspect would involve the marking of stocked and wild trout to see what proportions of these enter the 'angled' population, to estimate the size of the loch's trout population and to see which fish are vulnerable to cormorant predation.

13. ACKNOWLEDGEMENTS

We would like to thank Alan Lauder and Gordon Wright for their assistance in providing valuable data, particularly cormorant counts on Loch Leven, and for allowing us access to the unpublished records of Alan Allison. Willy Wilson kindly provided data on catches, hatchery releases and cormorant stomach contents (1981-1991). Wendy Mattingley collated cormorant counts for Perth and Kinross which were supplied by several local observers. Andy Walker gave us access to his unpublished data on Loch Leven trout growth rates and, along with Tony Baillie-Watts, discussed the Loch Leven fishery with us. Finally, we would like to thank the Secretary of the Association of Scottish Stillwater Fisheries and the various Fishery Managers and Angling Club Secretaries who all provided us with information about cormorants on their particular waters and expressed such interest in this work.

14. REFERENCES

Alstrom, P. (1985) Artbestamning av storskarv *Phalacrocorax carbo* och toppskarv *Ph. aristotelis*. *Var Fagelvarld* 44: 325-350.

Barlow, C.G. & Bock, K. (1984) Predation of fish in farm dams by Cormorants, *Phalacrocorax* spp. *Aust. Wild;* Res., 11: 559-566.

Broadway, R. (1989) Cormorants threaten aquaculture industry. *Aquacult Mag.* July/August 1989; 28-30.

Carss, D.M. & Marquiss, M. (in press) Avian predation at farmed and natural fisheries. Proc. 22nd Ann. Institute of Fisheries Management Study Course.

Clelland, B.E. (1979) A trout population survey at the major tributaries in August 1979. Loch Leven Research Group Report 1978-1979.

Coulson, J.C. & Brazendale, M.G. (1968) Movements of cormorants ringed in the British Isles and evidence of colony-specific dispersal. *Brit. Birds* 61: 1-21.

Craig, J.F. (1974a) Population dynamics of Perch, *Perca fluviatilis* L. in Slapton Ley, Devon. *Freshwat. Biol.* 4: 417-431.

Craig, J.F. (1980) Growth and production of the 1955 to 1972 cohorts of perch, *Perca fluviatilis* L., in Windermere. *J. Anim. Ecol.* 49: 291-315.

Craig, J.F., Kipling, C., Le Cren, E.D. & McCormack, J.C. (1979) Estimates of the numbers, biomass and year-class strengths of perch (*Perca fluviatilis* L.) in Windermere from 1967 to 1977 and some comparisons with earlier years. *J. Anim. Ecol.* 48: 315-325.

Cramp, S. & Simmons, K. (1977) The Birds of the Western Palearctic. Vol. 1., RSPB/Oxford University Press.

Draulans, D. (1987) The effectiveness of attempts to reduce predation by piscivorous birds: a review. *Biol. Conserv.* 41: 219-232.

EIFAC (1989) Report of the EIFAC working party on prevention and control of bird predation in aquaculture and fisheries operations. *Tech. Pap. EIFAC 51*, pp85, FAO, United Nations, Rome.

Feare, C.J. (1988) Cormorants as predators at freshwater fisheries. *Proc. 18th Ann.* Institute of Fisheries Management Study Course: 18-42.

Feltham, M.J. & Marquiss, M. (1989) The use of vertebrae in separating, and estimating the size of trout (*Salmo trutta*) and salmon (*Salmo salar*) in bone remains. *J. Zool.*, Lond. 219: 113-122.

Harris, M.P., Wanless, S. & Smith, R.W.J. (1987) The breeding seabirds of the Firth of Forth, Scotland. *Proc. R.S.E.*, 93B: 521-533.

Lack, P. (1986) The Atlas of Wintering Birds in Britain and Ireland. Poyser, London, pp447.

Lloyd, C., Tasker, M.L. & Partridge, K. (1991) The Status of Seabirds in Britain and Ireland. Poyser, London, pp355.

McCormack, J.M. (1965) Observation on the perch population of Ullswater. *J. Anim. Ecol.* 34: 463-478.

Moerbeek, D.J., van Dobben, W.H., Osieck, E.R., Boere, G.C. & Bungenberg de Jong, C.M. (1987) Cormorant damage prevention at a fish farm in the Netherlands. *Biol. Conserv.* 39: 23-38.

Morgan, N.C. (1974) Historical background to the International Biological Programme Project at Loch Leven, Kinross. *Proc. R.S.E.* (B), 73,3: 45-55.

Muckle, I. (1991) A season of discontent. *Trout Fisherman*, December 1991: 24-26.

Owen, M., Atkinson-Willes, G.L. & Salmon, D.G. (1986) Wildfowl in Great Britain. Cambridge University Press, Cambridge, pp613.

Pawson, M.G. (1991) Comparison of the performance of brown trout, *Salmo trutta* L., and rainbow trout, *Oncorhynchus mykiss* (Walbaum), in a put-and-take fishery. *Aquacult* Fish. Mgmt. 22: 247-257.

Sandison, B. (1992) Brown trout fishing in Scotland, a Trout and Salmon Guide. *Trout and Salmon*, EMAP Pursuit Publishing, Peterborough, pp46.

Sharrock, J.T.R. (1976) The Atlas of Breeding Birds in Britain and Ireland. Poyser, Berkhamsted, pp479.

Thom, V.M. (1986) Birds of Scotland. Poyser, Berkhamsted, pp382.

Thorpe, J.E. (1974a) Trout and perch populations at Loch Leven, Kinross. *Proc. R.S.E.* (B), 74, 20: 295-313.

Thorpe, J.E. (1974b) Estimation of the number of brown trout *Salmo trutta* (L.) in Loch Leven, Kinross, Scotland. *J. Fish Biol.* 6: 135-152.

van Vessem, J., Draulans, D. & De Bont, A.F. (1985) The effects of killing and removal on the abundance of grey herons at fish farms. XVIIth Congress of the International Union of Game Biologists, Brussels, Sept. 17-21, 1985 Report, pp337-343.

APPENDIX 1: Cormorant counts at three sites in Perth and Kinross, 1988-1991.

	1988	1989	1990	1991	
Jan.	1	5	-	6	
Feb.	-	13	-	-	
Mar.	11	12	-	-	
Oct.	17		28	50	Loch of Clunie
Nov.	-	-	-	38	
Dec.	-	-	2	27	
Mar.	-	3	14	20	Drummond Pond
Dec.	16	104	184	-	
Jan.	27	38	79	80	Perth Tree Roost
Feb.	22	28	67	-	

APPENDIX 2: The stomach contents of fish eating birds, Loch Leven NNR. Kinross-shire, 1971-1977. Data collected by Allan Allison (measurements originally in inches), Ad = adult, Imm. = immature, 1w = 1st winter, 2w = 2nd winter, m = male, f = female

CORMORANTS

17/2/72 0815-1030 hrs	Ad f Partially digested Brown Trout c254mm.
17/2/72 " "	1W f Perch fresh 267mm. (ringed 5044904).
17/2/72 " "	1W f Partially digested Brown Trout 222mm.
17/2/72 " "	2W f Partially digested Brown Trout c254mm.
17/2/72 " "	1mm m Fresh Perch 254mm.
17/2/72 " "	1mm f Partially digested Brown Trout c254mm.
29/2/72 0930 hrs	Ad m Recently taken Perch c254mm (Reed Bower - birds already perching on island by 074hrs)
29/2/72 1015 hrs	Ad f Recently taken Perch c241mm Head and forepart well digested. (Reed Bower).
3/3/72 1730-1830hrs	Ad m Half digested remains of Perch c229mm. Ringed M3495 & white plastic ring. (Flighting into Reed Bower to roost).
3/3/72	1W f Remains of spine of Perch.
3/3/72	1W f Well digested remains of Perch. Tail only recognisable.
8/3/72 0900hrs	3W f Freshly taken Perch c254mm (pricked bird, prob from 3/3)
17/3/72 1000hrs	2W f a small quantity of perch bones. (drowned in pike-net).
26/10/72 (daytime)	1mm m Recently taken Perch 241mm.
23/1/73 "	1mm m " " Perch 229mm.
25/1/73 "	1mm m Partly digested Brown Trout 356-381mm.
30/1/73 1630-1730 hrs	1mm f Well digested Brown Trout length?
30.1/73 " "	1mm m Recently taken Brown Trout c356mm.
30/1/73 " "	1mm m Recently taken Perch c229mm.
30/1/73 1630-1730hr	Imm f Partially digested Perch c229mm.
30/1/73 " "	Imm m Fresh Perch 102mm, recently taken Perch 216mm.
30/1/73 " "	1mm m Fresh Brown trout 203 mm & 2 part digested 127 & 178 mm. Well digested Perch at c127-152mm.
30/1/73 " "	Ad f Fresh Perch at 203mm & partly digested at 127mm each
11/3/74 0930-1030hrs	Ad (Reed Bower) Well digested remains of Perch c203mm.
11/3/74 " "	Ad (" ") " " " " " " c178mm.
25/10/74 (midday)	Ad Recently taken Perch 267mm.

7/11/74 (midday)	lmm Recently taken Perch 305mm (the largest Perch so far recorded).
18/12/75	12 (10 juvs and 2 adults) shot at roost on Reed Bower. 2 of juvs ringed on the Lamb in the Forth in June 1975. Juv empty Juv at least 30 Perch fry c76mm. 6 Juvs large trout 305+mm (3 with ova c5mm). 2 Juvs large Perch to 254mm. 2 Ads " " " "
15/1/76 (evening)	4 shot at roost on Reed Bower. Stomachs all with well digested fish. Juv 1 large trout. Juv Cram of Perch fry c 76mm stomach and gullet 40-50. Juv A quantity of small (c51mm) Perch 20-30.
18/2/76 (evening)	7 shot at roost at Reed Bower. Juv well digested fish. Juv " " Perch. Juv 2 " " " c178mm. Juv 2 " " " c178-203mm. 2 yr 1 Perch (c229mm) and 2 Perch fry, 1 trout (c229-254mm). 2 yr well digested trout c254mm. 2 yr " " " " , and 1 Perch fry.
?/10/76	10 shot Reed Bower and Castle Island. Juv Empty pike net. Juv 2 Perch 229 and 76mm. Juv 8 Perch at 114mm and 1 at 38mm. Juv 8 Perch at 102-127mm. Juv 7 Perch at 76-203mm. Juv 6 Perch at 102-152mm. Juv 10 Perch at 76-127mm. 2/3 yr 4 Perch at 102, 102, 102 and 203mm. 2/3 yr 2 Perch at 254mm. 2/3 yr 1 trout well digested.
22/2/77	4 shot Ad 2 Perch fry 76-102mm, and 1 trout of uncertain size. Ad 1 trout c254mm. Juv 2 Perch at 254mm. Juv 1 Perch at 102mm and 1 at 203-229mm.

12/10/77	8 shot Loch Leven.
	Juv empty ringed
	Juv 1 Perch at 229mm.
	2nd W 2 Perch at 178mm.
	2nd W fish remains
	2nd W 1 Perch at 254mm.
	2nd W 2 Perch at 127 and 76mm.
	2nd W 1 Perch at 254mm.
	2nd W 1 Perch at 254mm+.

APPENDIX 3. Details of Cormorants examined Spring 1992.

No.	Date	Sex	Age	(Wt.g)	Stomach Contents
1	19.1.92		Imm	2775	Scales from regurgitated trout = 18cm
2	"		Imm	2845	Trout = 18, 21, 16cm
3	4.2.92	♀	AD	1960	Empty
4	"		AD	4725	Trout = 43cm
5	"	♀	AD	2755	Trout = 31cm
6	"		Imm	3510	Trout = 25, 26cm
7	5.2.92		AD	4055	Trout (head only) not measured
8	"		Imm	4315	Trout = 41 cm, Stickleback = 0.4cm
9	"		Imm	3265	Trout = 32 cm
10	14.2.92		Imm	3860	Empty - mammal bone (carrion)
11	"		Imm	3060	Perch = 15, 18 cm
12	"		AD	3760	Trout = 45 cm
13	"		AD	3340	Empty
14	"		AD	3870	Trout = 31 cm (+ perch scales present)
15	17.2.92	♀	AD	2520	Empty - very eroded salmonid and stickleback bones
16	20.2.92	♂	AD	2160	Trout = 6, 9, 11 cm
17	4.3.92	♀	AD	2805	Trout = 31 cm
18	"	♂	AD	3585	Trout = 25 cm, Perch = 14 cm, Stickleback = 4, 3, 3, 3, 4 cm
19	"	♀	Imm	3205	Trout = 21 cm
20	7.3.92	♂	Imm	3070	Empty

ITE has six Research Stations throughout Britain, which allows the efficient use of resources for regional studies and provides an understanding of local ecological and land use characteristics. The Institute's administrative headquarters is at Monks Wood.

ITE sites

Monks Wood
(Admin HQ)
Abbots Ripton
HUNTINGDON PE17 2LS
Telephone 01487 773381-8
Fax 01487 773467
Email MONKSWOOD@ITE.AC.UK

Merlewood Research Station
GRANGE-OVER-SANDS
Cumbria LA11 6JU
Telephone 015395 32264
Fax 015395 34705
Email MERLEWOOD@ITE.AC.UK

Edinburgh Research Station
Bush Estate
PENICUIK
Midlothian EH26 0QB
Telephone 0131 445 4343
Fax 0131 445 3943
Email BUSH@ITE.AC.UK

Furzebrook Research Station
WAREHAM
Dorset BH20 5AS
Telephone 01929 551518-9, 551491
Fax 01929 551087
Email FURZEBROOK@ITE.AC.UK

Banchory Research Station
Hill of Brathens
Glassel, BANCHORY
Kincardineshire AB31 4BY
Telephone 01330 823434
Fax 01330 823303
Email BANCHORY@ITE.AC.UK

Bangor Research Unit
University of Wales, Bangor
Deiniol Road
BANGOR, Gwynedd LL57 2UP
Telephone 01248 370045
Fax 01248 355365
Email BANGOR@ITE.AC.UK

Details about the Institute are available on the Internet via the World Wide Web (http://www.nmw.ac.uk/ite)