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THE STOMACH CONTENTS OF CORMORANTS FROM LOCH LEVEN, 1992-94

D N CARSS & M MARQUISS

Institute of Terrestrial Ecology
Banchory Research Station
Hill of Brathens
Banchory
AB31 4BY

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SUMMARY

1 The possible conflict between cormorants (*Phalacrocorax carbo*) and the trout (*Salmo trutta, Onchorhynchus mykiss*) at Loch Leven, Kinross was further investigated by examination of cormorant stomach contents.

2 Cormorant samples were obtained in the winters of 1992/93 (n = 56) and 1992/93 (n = 45).

3 In general cormorant diet was dominated by salmonids with smaller numbers of perch *Perca fluviatilis* and three-spined *Gasterosteus aculeatus* recorded. The size and proportions of these fishes in the diet of cormorants is discussed.

4 Some samples collected after the introduction of rainbow trout into the loch in the spring of 1993 contained the remains of this species. Overall, rainbow trout comprised up to 15% of the diet by number and up to 29% by weight.

5 The potential for conflict between birds and the fishery is discussed along with aspects requiring further study.

1 INTRODUCTION

As part of its objectives of protecting and enhancing the natural heritage, Scottish Natural Heritage must have available adequate information on the ecology and behaviour of species present in this country. This present contract seeks to obtain data on the diet of cormorants (*Phalacrocorax carbo*) at Loch Leven.

In winter 1991/92 a study of the diet of cormorants was undertaken at Loch Leven NNR by staff from ITE, Banchory. Corpses of cormorants shot for "fisheries protection" were provided by staff from Kinross Estate. A substantial report was produced (Carss & Marquiss, 1992), detailing the findings of that single seasons work, reviewing historical data on numbers and diet, and examining the potential for preventative measures to reduce the impact of these birds on brown trout (*Salmo trutta*) stocks. In 1992/93 further corpses were provided and data were collected on a purely voluntary basis by ITE, no analysis was funded by SNH.

The introduction of rainbow trout (*Oncorhynchus mykiss*) into the loch in the spring of 1993 was a significant event in the management of the fishery. The results of our previous study showed cormorants consumed large numbers of Loch Leven brown trout in the winter months. There is now more information on fish stocks (O'Grady, Gargan & Roche, 1993 and subsequent monitoring) so this predation can be better evaluated in terms of the potential economic loss to the fishery. Moreover it was anticipated that cormorant diet would change associated with the introduction of rainbow trout. The present study therefore set out to estimate the diet of birds in the winter 1993/94, and review diet over the whole period within the context of cormorant impact on the fishery.

The relationship between cormorants and trout not only has potential implications for the

Loch Leven fishery and for the status of cormorants, but may have applications in similar situations further afield in Scotland.

2 AIMS

The present study has three aims:

(1) To analyse the stomach contents of cormorants collected at Loch Leven during 1992-1994 to search for trends in diet.

(2) To review these results in relation to the introduction of rainbow trout and the latest fishery data from the loch.

(3) To identify aspects of Cormorants predation and the Loch Leven Trout Fishery which require further research.

3 METHODS

Cormorants were collected by Estate staff from Loch Leven, Kinross, eastern Scotland (Fig. 1), they were frozen as soon after death as possible and later thawed for examination. Birds were weighed and age was determined from plumage (Alstrom, 1985) with "adults" (i.e. three years old, or older) having dark blue-green breasts and those of younger birds ("immatures") being paler with varying amounts of white feathers. Sex was determined by internal examination. From each birds, the stomach (including the oesophagus) was removed and the contents washed into a beaker.

Only recent meals were included in the analyses because the use of well digested remains can introduce serious bias in estimates of diet (Johnstone, Harris & Graves, 1990). Some

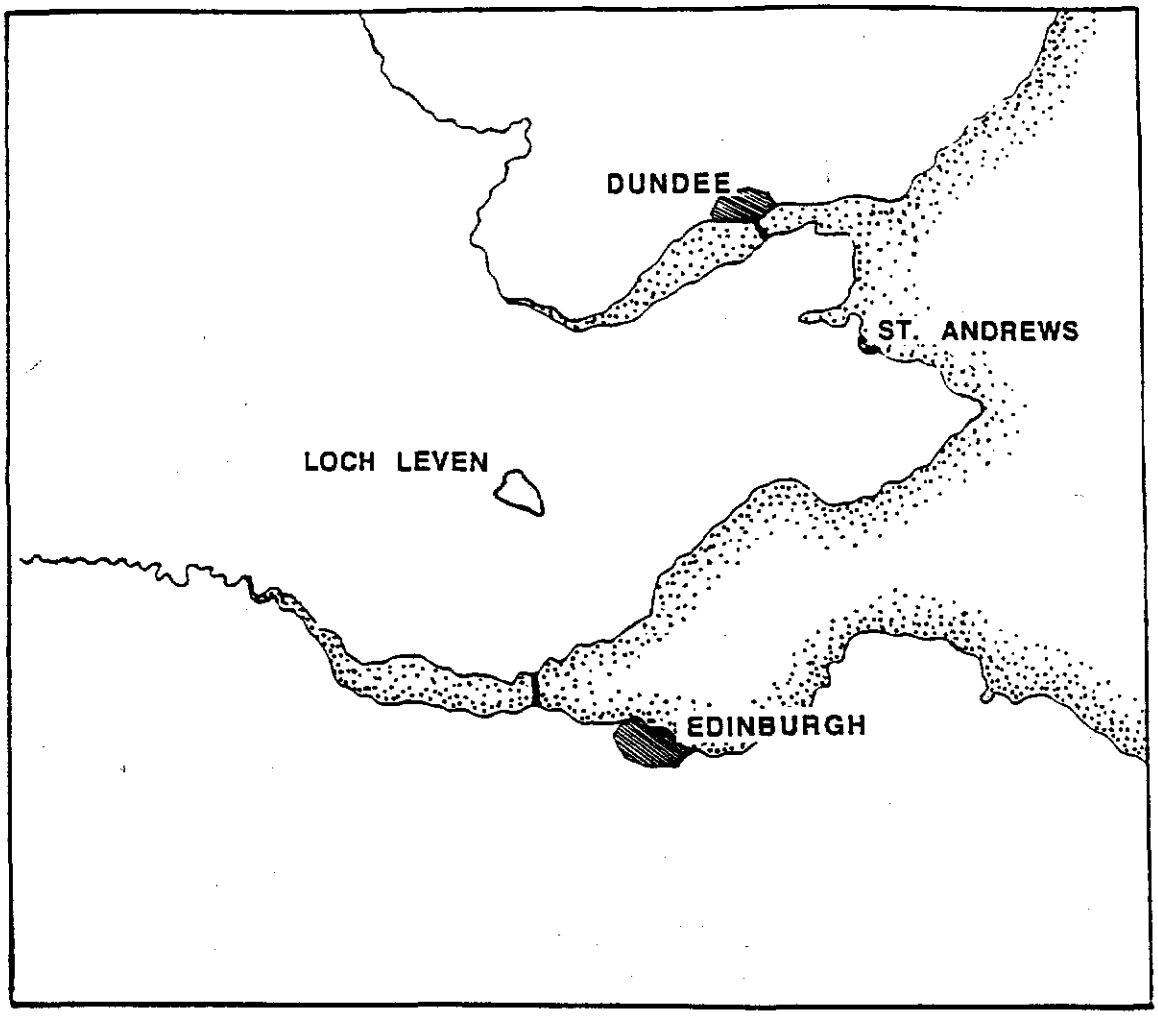

Figure 1. Map showing the location of Loch Leven

stomachs contained the remains of previous well-digested meals but the characteristic worn and eroded bones from these were excluded. Whole fish were identified using Wheeler (1978), and their lengths measured. Partially digested fish were soaked in a solution of biological washing powder to remove the remaining flesh and the resulting skeletons were examined and reference material and keybones removed. These keybones, including atlas and caudal vertebrae (salmonids), pelvic girdles, lower jaws and opercular bones (stickleback *Gasterosteus aculeatus* and perch *Perca fluviatilis*), were used for identification and to estimate fish lengths, and hence fresh weights, by a series of regression relationships (Table 1).

Comparisons were then made based on the species composition and length frequency distribution of the fishes consumed.

4 AGE STRUCTURE

A total of 101 cormorants killed at Loch Leven during 1992-1994 were examined (see Appendix 1 for details of 1993/94 birds), of these 30 (29.7%) were adult.

5 DIET

Winter samples were split into "early" (November/December) and "late" (January/February) depending on the time of death for both 1992/3 and 1993/4 (pre-and post-rainbow trout stocking, respectively) giving four samples. From a total of 101 birds examined, 71 (70.3%) contained food (Table 2, Fig. 2). For all samples the diet was dominated, both numerically

Table 1. (a) Regression equations for various fish key bone measurements (mm) against fork length (FL, cm), (b) length: weight relationships for the same fishes, Wt = wet weight (g), L = fish length (cm).

(a) Key bone	Relationship	Source
Pike lower jaw	Log FL = -0.192 + 1.01 Log J	Carss & Brockie (1994)
Perch lower jaw	Log FL = 0.0684 + 1.01 Log J	Carss & Brockie (1994)
Perch preoperculum	Log FL = 0.0014 + 0.955 Log P	Carss & Brockie (1994)
Perch operculum	Log FL = 0.207 + 0.873 Log OP	Carss & Brockie (1994)
Salmonid lower jaw	Log FL = 0.0664 + 0.982 Log J	Carss & Brockie (1994)
Salmonid atlas	Log FL = 0.761 + 1.08 Log At	Carss & Brockie (1994)
Brown trout cleithra	Log FL = -0.0475 + 1.04 Log Cl	Carss & Brockie (1994)
Rainbow trout cleithra	Log FL = 0.0298 + 0.96 Log Cl	Carss & Brockie (1994)
(b)		
Perch	$Wt = 0.0135L^{3.0}$	Craig (1974)
Pike	$Wt = 0.005248L^{3.09}$	Frost & Kipling (1967)
Brown trout	$Wt = 0.0195L^{2.822}$	Clelland (1979)
Rainbow trout	$Wt = 0.0101L^{3.05}$	Carss (1993)

Table 2. Cormorant diet at Loch Leven in 4 periods by number and weight of fishes recorded in stomachs.

	Nov/Dec 1992		Jan/Feb 1993		Nov/Dec 1993		Jan/Feb 1993	
	No	Wt	No	Wt	No	Wt	No	Wt
Brown Trout	29.3%	95.1%	73.1%	89.7%	34.5%	70.4%	56.4%	77.2%
Rainbow Trout	0	0	0	0	6.9	28.7	15.4	19.5
Perch	43.9%	4.7%	18.4%	10.3%	37.9%	0.8%	17.9%	3.3%
Stickleback	26.8%	0.2%	7.9%	0.1%	20.7%	0.1%	10.3%	0.1%
$\sum$ = 100%	41	2361g	38	7449g	29	2982g	39	11939g
No stomachs with food	12		25		10		24	

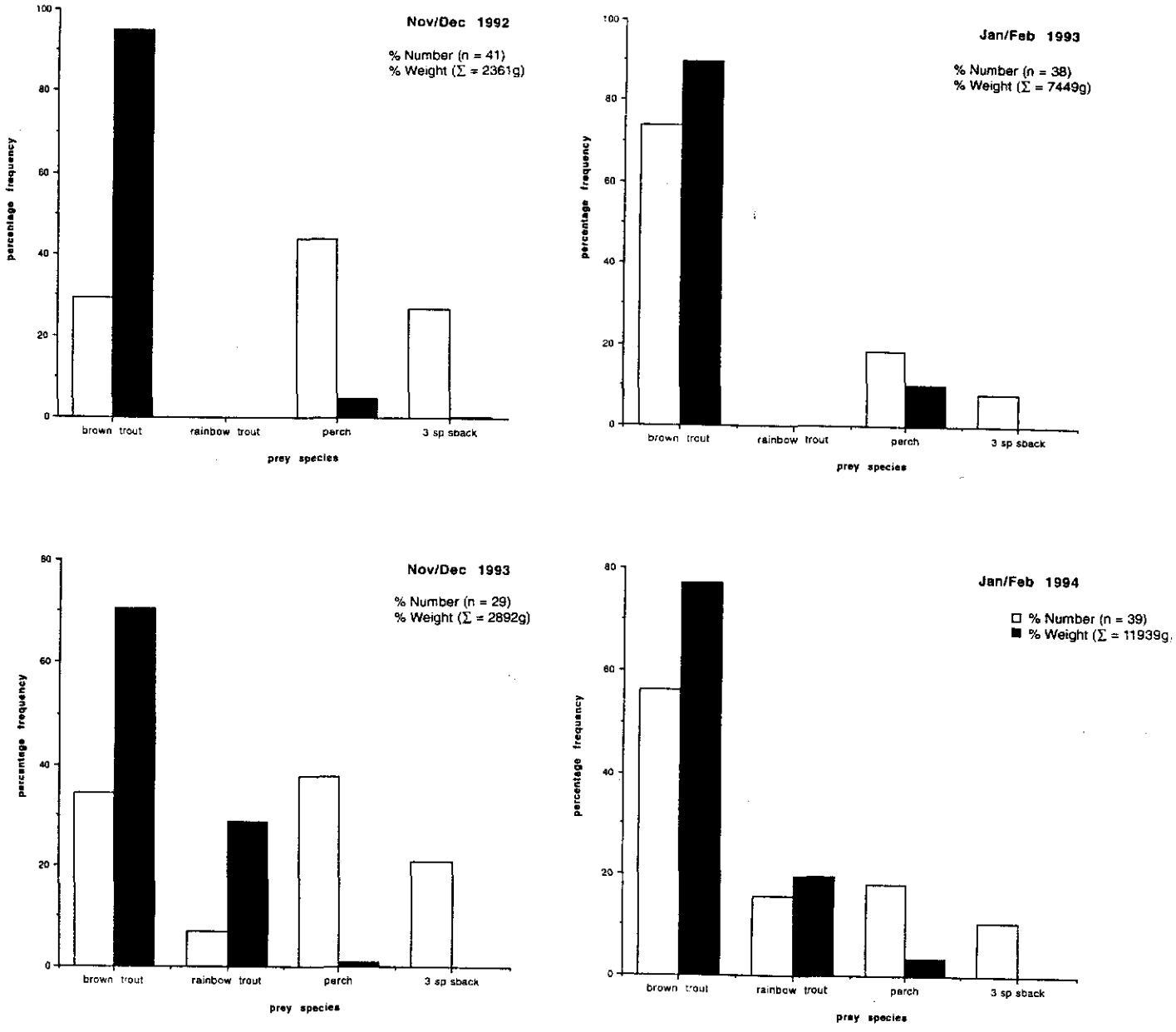

Figure 2. Cormorant diet at Loch Leven, Nov-Feb 1992/3, Nov-Feb 1993/4.

and in terms of mass, by trout. No rainbow trout were recorded in the diet of birds killed in the 1992/93 samples, but this species constituted 21% of the diet by mass the following year (Table 3, Fig. 3).

Previous estimates of cormorant diet at Loch Leven (Carss & Marquiss, 1992) suggested a change had occurred over the last 20 years, with more trout being taken and fewer perch. For analysis, stomachs containing fish were categorised as containing either trout or perch and samples were split into three 6-year periods. Similar analysis including the latest samples show that this change is still evident ($\chi^2 = 18.1$, df = 3, $p < 0.001$, Table 4). The proportions of stomachs containing trout and perch have remained similar since 1987 ($\chi^2 = 0.31$, df = 1, NS, Table 4).

6 THE SIZE OF TROUT TAKEN

Previously the median length of brown trout taken by cormorants at Loch Leven was 25 cm (Carss & Marquiss, 1992). In the present study the forty brown trout eaten in the 1992/93 winter also had a median length of 25 cm (range 15.5 - 53.8 cm). Although brown trout (n = 32) from the following winter had a median length of 29 cm (range 15.5 - 47.9 cm), this was not significantly different from the previous sample (Mann-Whitney U-test, W = 1254, NS). The length frequency of brown trout (n = 72) from the 1992/93 and 1993/4 samples is shown in Figure 4. Over this period, most (78%) of the brown trout taken by cormorants were over ca. 9 ins. (23 cm) and so large enough to have been kept by anglers. The remainder were below "takable" size.

Rainbow trout were only recorded in the stomachs of cormorants after this fish had been introduced into the loch in the spring of 1993. The subsequent 1993/94 sample contained

Table 3. Cormorant diet at Loch Leven during the 1992/93 and 1993/94 winters by number and weight of fishes recorded in stomachs.

	Nov-Feb 1992/3		Nov-Feb 1993/4	
	No.	Wt.	No.	Wt.
Brown Trout	0.6%	91.0%	47.1%	75.8%
Rainbow Trout	0	0	11.8	21.3
Perch	31.6	8.91	26.5	2.8
Stickleback	17.7	0.1	14.7	0.1
$\sum$ = 100%	79	9810g	68	14831g
No stomachs with food	37		34	

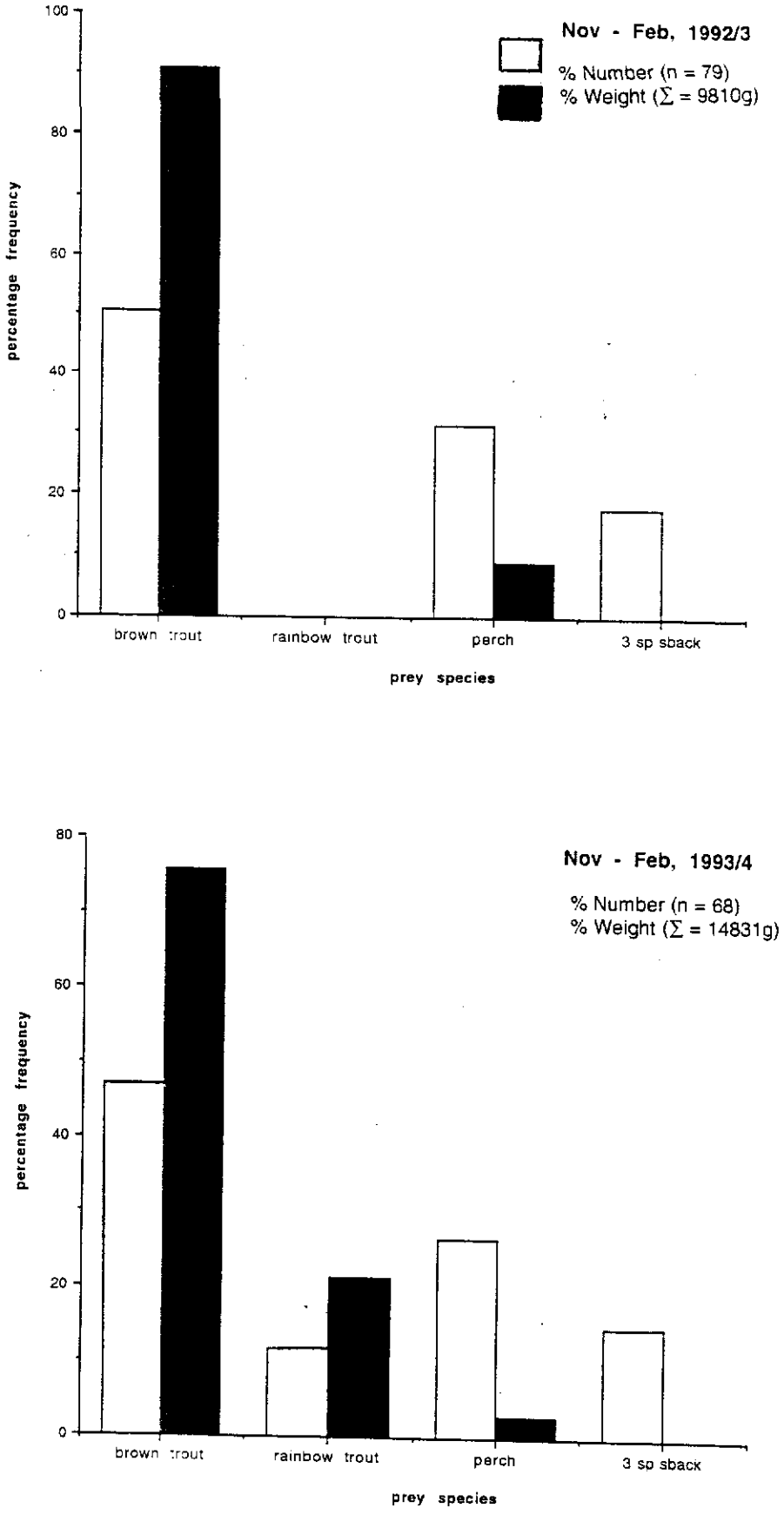

Figure 3. Cormorant diet at Loch Leven, 1992/3 and 1993/4 winters.

Table 4. Percentage of cormorant stomachs containing either trout or perch in the 4 periods; 1972-77, 1981-86, 1987-92 (data from Carss & Marquiss 1992) and 1992-94 (present study).

	No of stomachs containing food	Percentage of stomachs containing	
		Trout	Perch
1972-77	67	30	70
1981-86	262	54	46
1987-92	368	84	16
1992-94	70	81	19

eight rainbow trout with a median length of 34 cm (range 26-39 cm). These fish were significantly larger than the brown trout (median = 29 cm) taken by cormorants over the same period (see above, Mann-Whitnely U-test, W = 626, P = 0.001). All the rainbow trout taken were large enough to have been kept by anglers (Fig. 4).

7 THE SIZE OF PERCH TAKEN

In the spring 1992 sample (Carss & Marquiss, 1992) only two perch were recorded, measuring 15 and 18 cm, respectively. A total of 43 perch were recorded in the 1992/4 samples, mostly form birds shot in November/December. These fish (n = 29) were smaller than those (n = 14) taken later in the year during January/February (Fig. 5). Perch taken in November/December had a median length of 5 cm, those taken in January/February had a median length of 14 cm.

8 DISCUSSION

Cormorant Age Ratios

Shooting adult cormorants might have a greater impact on populations than shooting immature birds (Carss, 1994). Interest was expressed by Carss and Marquiss (1992) that a higher proportion of cormorants in the spring 1992 sample (n = 20) were adult compared with earlier figures from the loch. This suggested that the proportion of adult cormorants at the loch had increased since 1972. The proportions of adults in samples from winter 1992/93 and 1993/94 (n = 101) was 30% close to those from elsewhere in Scotland (unpublished data in Carss and Marquiss, 1992). This suggests that the age ratios at the loch are probably variable, but overall, similar to elsewhere.

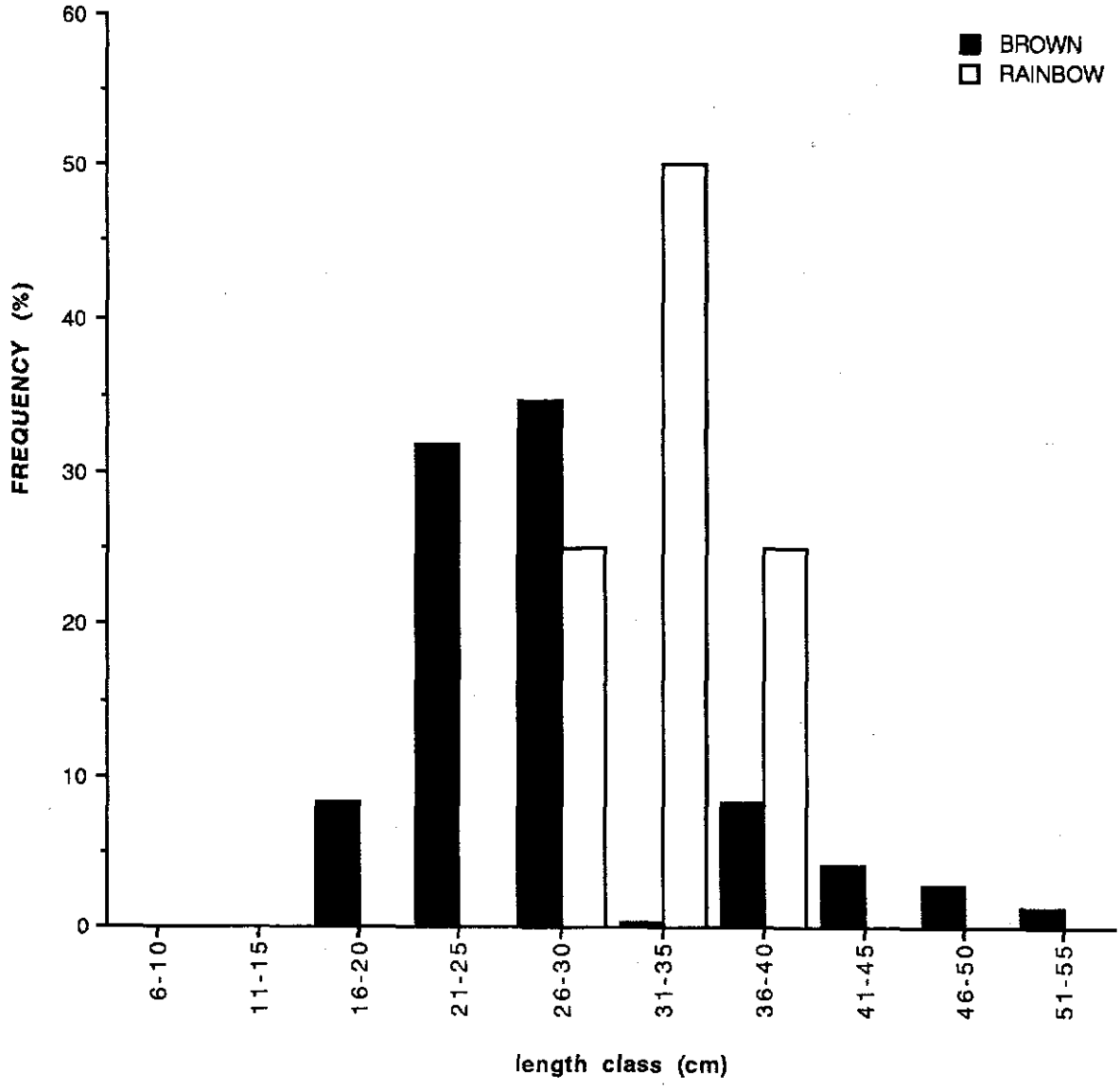

Figure 4. Length frequencies of brown and rainbow trout consumed by cormorants at Loch Leven, winter 1993/94.

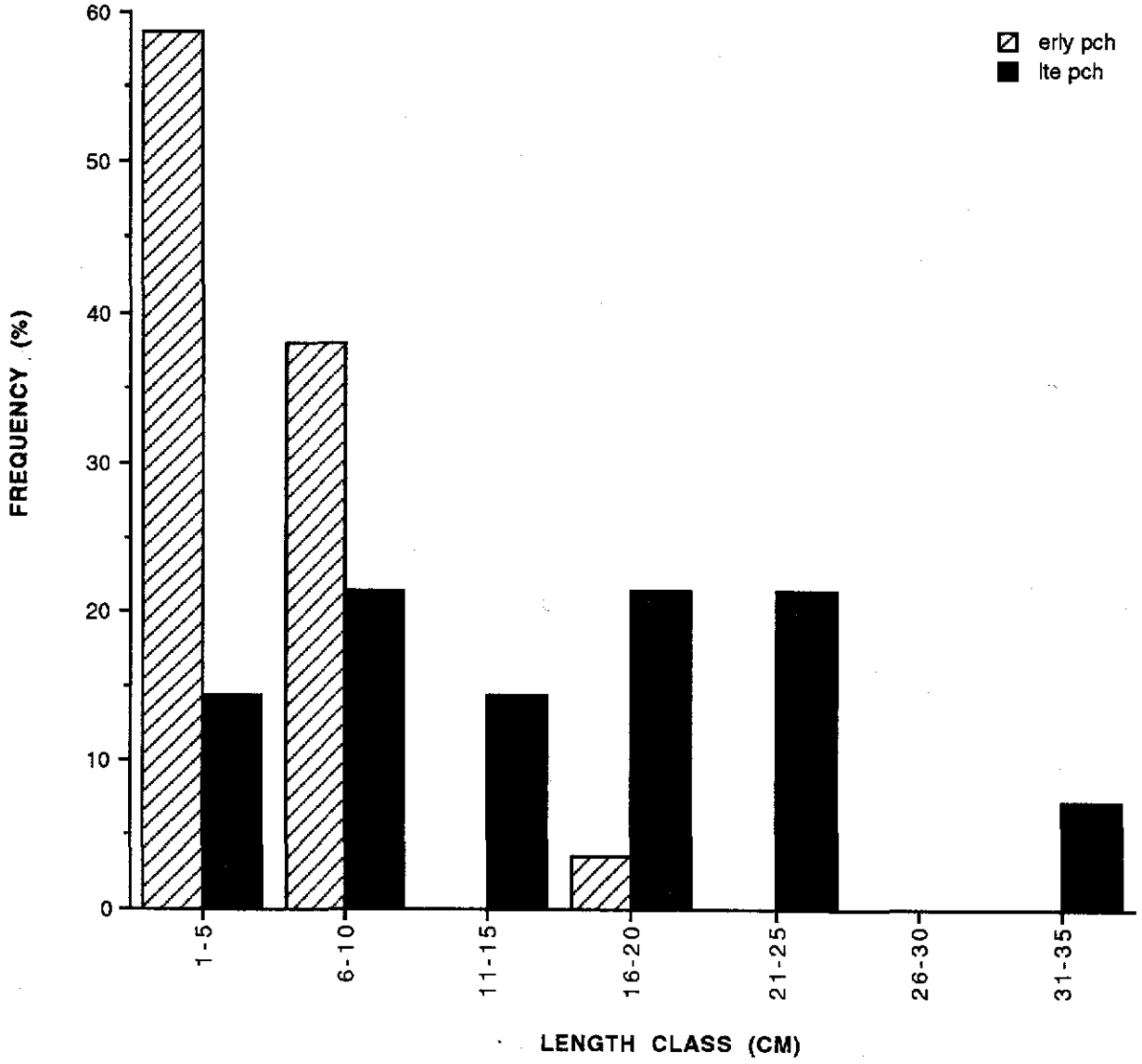

Figure 5. Length frequencies of perch consumed by cormorants at Loch Leven, 1992/3 and 1993/4 winters

Perch in the Diet

The present study endorses previous work at Loch Leven (Carss and Marquiss, 1992), cormorants take mostly trout and some perch. Perch constitute a small proportion of the diet but the size of fish taken varied seasonally with the smallest fish being taken in November/December and larger ones in January/February. The reason for this is unknown but there are a number of possibilities. For instance there may be a behavioural shift: smaller fry becoming inactive and forming large, cover-seeking shoals, thus lowering their predation risk (Johnson & Evans 1991). It may be unprofitable for cormorants to search for such aggregations of small fish and they may switch to large, solitary individuals.

Rainbow Trout in the Diet

The winter diet of cormorants in 1992/3 was very similar to that in the spring of 1992 (Carss and Marquiss, 1992), being dominated by brown trout with smaller numbers of smaller perch and three-spined stickleback. Soon after the spring 1992 sample was taken, 40 000 rainbow trout were introduced into the loch. In the following winter (1993/4) proportions of salmonids were similar to 1992/93, but rainbow trout comprised 7-15% of the diet by number and 20-29% by weight. The ratio of rainbow to brown trout in stomach contents was 0.25:1. Accurate estimates of the true populations of rainbow to brown trout in the loch are unavailable but current best estimates indicate that by the end of the 1993 angling season the proportion of rainbow to brown trout was 0.07:1 (A. Lauder, pers. comm.). Thus it appears that rainbow trout occur in the diet of cormorants more than might be expected, however levels of uncertainty associated with estimates of trout numbers in the loch mean that any statistical test of this difference would be invalid.

Selective Predation for Size

The most commonly recorded size class of brown trout taken by cormorants was 26-30 cm.

Although this was similar to catches of brown trout (n = 518) during the March 1993 survey (O'Grady, Gargan and Roche, 1993), it appeared that cormorants were not taking brown trout in relation to their relative abundance. Of the estimated 400 000 brown trout in the loch 254000 (63.5%) were 1+ and 2+ fish with mean lengths of 11 and 25 cm, respectively. Moreover, because of the selectivity of the fishing gear, no fish less than 19.8 cm were sampled. Thus many of the small (7-15 cm) 1+ brown trout stocked in April 1992 (n = 188000) would not have been sampled. Cormorants therefore appeared to take fewer small brown trout than would be expected from their relative abundance, selecting larger (>25 cm) fish.

Although samples were small, rainbow trout taken by cormorants were larger than the brown trout. Many of the rainbow trout taken were amongst the largest present in the loch. Despite brown of similar, and larger, size being present in the loch, (see Figs. 18, 20 in Duncan, 1994) they were not taken. This suggests selection for larger rainbow trout in preference to similar sized brown trout.

Cormorant Predation and the Fishery

As suggested previously (Carss and Marquiss, 1992), there could be a significant, but as yet unestablished, loss to the trout population of Loch Leven of the order of several thousand fish. Despite reservations about sampling methods, recent population estimates (O'Grady, Gargan and Roche, 1993) suggest that the brown trout population of the loch may be high, and probably higher than Thorpe's (1974) estimates for 1968-71. However, direct comparisons are difficult because of differences in sampling procedures. For example, 2+ and older trout were sampled in 1993, but only 3+ and older in 1968-71. Furthermore, although seldom recorded in recent cormorant dietary samples, the much larger population of smaller

trout in the loch as a direct result of stocking measures is probably large enough to explain the apparent increase in use of the loch by cormorants.

Traditional methods of reducing cormorant predation at Loch Leven are unlikely to be effective. As previously discussed (Carss and Marquiss, 1992), (1) shooting cormorants will be ineffective as birds using the loch are drawn from a very large, and probably increasing, population, (2) scaring birds is ineffective on waters as large as Loch Leven, (3) cormorant predation on over-wintering trout may be reduced by "fishing down" their numbers and stocking only early in the season but this has only been investigated on smaller put-and-take fisheries. The occurrence of rainbow trout in the diet of the latest samples of cormorants suggests that it might be worthwhile providing an easily caught prey species but of relatively low value, such as perch. O'Grady, Gragan and Roche (1993) suggested that perch could be a principal competitor with trout but that if stocks recovered to levels recorded in the early 1970s (Thorpe, 1974), a commercial fishery could generate additional income and help reduce such competition. However, if perch populations did recover, or were enhanced by specific management policies, cormorant predation on trout may be reduced. At present it is neither possible to determine whether cormorant predation is having a negative impact on the fishery in terms of reducing angling catches, nor whether a switch to perch would reduce any such impact. Angling catches at Loch Leven have fluctuated but there is no evidence that the recent low catches (see Carss and Marquiss, 1992) have come from a reduction in fish stocks. Estimates of trout stocks (3+ and older) of the loch in 1993 were similar to those calculated in 1969 and that there has been no recent fall in recruitment levels of these larger fish Moreover, O'Grady, Gragan and Roche (1993) suggested that the stock of these adult trout was probably approaching the present carrying capacity of the loch. In contrast, angling effort has declined in recent years in association with dense algal blooms with no angling taking place after June in 1991 and 1992. The abundance of fish suggests that cormorant

predation is not a problem, in terms of angling harvest, at the loch and so the killing of birds should be discontinued as a fishery management technique.

Many of the proposed options for fishery management at the loch, for example eliminating or reversing eutrophication, monitoring fish stocks and stocking programmes, are long-term and relatively expensive. There may be therefore be a lobby for cheaper, short-term measures. In this context predator control is often seen as a legitimate management strategy, the perception being that because the size of fish taken by cormorants and anglers overlaps, a reduction in cormorant numbers would result in an increase in the numbers of fish harvested by anglers. It is widely thought that cormorants reduce harvest rates though there is no hard evidence for it (see review in Marquiss and Carss, 1994). If such perceptions persist, despite current suggestions to the contrary, attempts must be made to measure the impact of cormorants by calculating the amount of fish they remove. This would require estimates of the numbers of cormorants feeding at the loch, the turnover of birds and the effects on the remaining fish of the removal of others.

9 ACKNOWLEDGEMENTS

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APPENDIX: Details of cormorants examined in (a) Nov/Dec 1993 and (b) Jan/Feb 1994.

No.	Date	Sex	Age	Wt(g)	Stomach Contents
77	a	M	Imm	3790	Empty
78	a	M	Imm	4075	Brown trout = 33 cm Stickleback = 3,4,5,4 cm
79	a	M	Ad	3590	Brown trout = 21 cm
80	a	F	Imm	2975	Brown trout = 33 cm
81	a	-	Imm	3885	Brown trout = 24 cm
82	a	F	Imm	2770	Brown trout = 20 cm Unid. salmonid = 24 cm
83	a	F	Imm	2745	Rainbow trout = 34 cm
84	a	F	Ad	2255	Empty
85	a	F	Imm	3090	Unid. salmonid = 31 cm Perch = 5 cm
86	a	-	Imm	4050	Brown trout = 24, 32 cm
87	a	F	Imm	2730	Empty
88	a	F	Imm	2995	Empty
89	a	F	Imm	2010	Empty
90	a	F	Imm	2860	Brown trout = 26 cm Perch = 4, 5, 5, 5, 5, 5, 5, 6, 6, 6, cm Stickleback = 4, 4 cm
91	a	F	Imm	2665	Brown trout = 21 cm
92	a	F	Ad	2800	Empty
93	a	-	Imm	3540	Empty
94	b	M	Ad	4410	Brown trout = 43 cm
95	b	M	Ak	3705	Rainbow trout = 39 cm
96	b	M	Imm	4025	Empty
97	b	M	Imm	4090	Brown trout = 36 cm
98	b	-	Imm	3445	Perch 5 cm
99	b	M	Imm	2955	Empty
100	b	M	Imm	3465	Brown trout = 48 cm Rainbow trout 36 cm
101	b	F	Imm	3650	Brown trout = 28 cm Unid. salmonid = 28 cm Perch = 12 cm
102	b	M	Imm	3015	Rainbow trout = 26 cm
103	b	-	Imm	3015	Brown trout = 37 cm Unid. salmonid = 26 cm
104	b	M	Imm	3600	Brown trout = 42 cm Stickleback = 4 cm (Perch scales present)
105	b	F	Imm	3080	Brown trout = 35 cm Perch = 16 cm
106	b	M	Ad	3705	Brown trout = 16 cm
107	b	F	Ad	2850	Perch = 21 cm
108	b	M	Ad	3540	Brown trout = 33 cm

(Appendix continued)

No.	Date	Sex	Age	Wt(g)	Stomach Contents
109	b	M	Ad	3310	Rainbow trout = 35, 27 cm
110	b	M	Imm	4115	Brown trout = 41 cm Perch = 24 cm
111	b	M	Imm	3405	Empty
112	b	F	Ad	-	Brown trout = 27, 24 cm
113	b	F	Ad	2525	Perch = 6 cm Stickleback = 3 cm
114	b	M	Imm	3650	Brown trout = 26 cm
115	b	F	Ad	3015	Unid. salmonid = 29 cm Stickleback = 3, 4 cm
116	b	M	Ad	3585	Empty
117	b	M	Imm	3265	Brown trout = 47 cm
118	b	F	Ad	2915	Perch = 10 cm
119	b	M	Ad	4025	Brown trout = 29, 36 cm
120	b	F	Ad	3270	Brown trout = 32 cm
121	b	M	Ad	3820	Rainbow trout = 34 cm

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