Avian Piscivores: Basis for Policy

Institute of Terrestrial Ecology

R&D Project Record 461/8/N&Y

NRA
National Rivers Authority

Avian Piscivores: Basis for Policy

M Marquiss & D N Carss

Research Contractor:
Institute of Terrestrial Ecology

National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS12 4UD

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Research Contractor
This document was produced under R&D Project 461 by:

Institute of Terrestrial Ecology
Hill of Brathens
Glassel
Banchory
Kincardineshire AB31 4BY

Tel: 0330 823434 Fax: 0330 823303

NRA Project Leader
The NRA's Project Leader for R&D Project 461 was:

Dr John Hogger - NRA Northumbria and Yorkshire Region

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EXECUTIVE SUMMARY

1. In Britain, many birds eat fish in freshwaters but only three species, cormorant, red-breasted merganser and goosander, are commonly perceived to present serious problems for freshwater fisheries. Complaints are mainly that cormorants eat large fish and that all three bird species eat so many juvenile fish, that there are subsequently fewer fish to be harvested or angled, but also that persistent predation by birds changes fish behaviour so that they are less 'catchable'.

2.1. Cormorant

2.1.1. Two subspecies of cormorant occur in Europe. *Phalacrocorax carbo carbo* breeds in the north and west, including Britain, and is mainly resident. The other race *P.c.sinensis*, an EC Directive, Annex I species, breeds elsewhere and is migratory, most moving south and east for the winter. Some *sinensis* winter in southeast England and a very few breed there.

2.1.2. A review of European studies shows cormorants take a large variety of fish associated with the wide range of habitats used. They can commute far to feed and they may preferentially select for prey species, prey size, and for foraging habitat. Such behaviour has important implications for predicting the use of sites, and for any attempts at managing cormorant populations. Their average food intake is between 340 g and 520 g fish per day.

2.1.3. Recently the *sinensis* population has increased at about 21% per annum, to about 105000 pairs (1992).*Carbo* populations have increased at about 3-6% per annum, to about 40000 pairs. In Britain, numbers have increased most in the southeast and could have declined in parts of Scotland. The British winter population has increased, the numbers in freshwaters associated with increases in stocked fisheries.The most recent estimate (1990) is 16800 birds.

2.1.4. The increase in cormorant populations has been attributed to a reduction in killing by man, a reduction in environmental pollutants, and an increase in food supply, but the evidence is insufficient to distinguish between these factors. Eventually the population in Britain will stabilise, its size proportional to the amount of available food, but this process can be expectedto be prolonged if their food supply continues to be increased artificially.

2.2. Goosander

2.2.1. The goosander is a predominantly freshwater duck breeding mainly on rivers. In Britain, most move relatively short distances to winter on the lower parts of rivers, estuaries and freshwater lakes. Their life cycle, breeding and movements are described.

2.2.2. The diet consists of the most easily caught small (5-11 cm) fish, of those most abundant in the various habitats used by the birds. The only areas where goosanders have been shown to consume large numbers of fish of economic interest, are in places where the fish community is dominated by such fish. Naive hatchery fish seem to be particularly vulnerable.

2.2.3. A recent spread in breeding range has been well documented, and further major expansion in Britain seems unlikely. The current breeding population has been estimated at 2700 pairs, with the greatest concentration in southern Scotland and northern England. The winter population has been most recently estimated at 5500. Recent counts have shown constant numbers in winter on three rivers in Scotland, but a major decline at the single largest winter concentration, and a decline in breeding birds on two of three regularly counted Scottish rivers.

2.3. Red-breasted merganser

2.3.1. Red-breasted mergansers are predominantly marine ducks of shallow coastal waters, only a small proportion breeding in the slower-flowing lower reaches of rivers, and on lakes. They spend the winter on the coast, entering freshwaters in late April or May, and leaving from June to September. Their life cycle, breeding and movements are described.

2.3.2. They eat mainly small (2-10cm) fishes, but also large insects and shrimps. Only on some rivers in Scotland have they been shown to eat fish of commercial importance. There they sometimes ate small juvenile salmon, but only in quantity during April.

2.3.3. In Britain numbers have increased with an expansion of breeding range into England and Wales, although most are still found in western Scotland. Further dramatic changes seem unlikely and much of the current population (estimated at 2,150 pairs) breeds on the coast.

3. The impact of birds on fish populations

3.1. Both the predators and prey of fish can influence fish populations so neither an effect of bird predation, nor the lack of one, can be assumed. Any postulated impact of fish-eating birds thus needs to be demonstrated unequivocally but, in the absence of properly controlled field experiments, it is easier to disprove an effect of birds than to show it.

Cormorants

3.2. Cormorants feed on the the large concentrations of wild and escaped fish in the waters immediately adjacent to cage farms but also attack stock through the net meshes. The amount of stock lost is small and can be further reduced by using properly positioned, underwater netting. There is little evidence that cormorants are a problem at tank or pond farms in Britain but in other parts of the world, losses can be substantial. There is also anecdotal evidence that flocks of cormorants landing on ponds, or beside cages cause stress to fish.

3.3. The concentration of fish at fish farms is so attractive to birds that shooting is usually ineffective. Excluding cormorants can be difficult and scaring only partially successful. Cage enclosures within ponds may protect small fish and changing the stocking regime and providing alternative (low commercial value) foods has been successful.

3.4. In Britain the number of stocked stillwaters has increased dramatically and in winter, cormorants can aggregate at such sites where they can feed on 'takeable' stocked fish. However, it has still to be shown that reducing cormorant predation results in greater catches for anglers.

3.5. If cormorants are reducing catches the problem is difficult to solve. On large water bodies exclosure is impossible, and deterrents and shooting are ineffective. Potential remedies include reducing the stocking density or the timing of stocking of the quarry species, and increasing alternative cormorant forage by stocking 'buffer' populations of low value fish.

3.6. On very large lakes cormorants can number hundreds or thousands. The evidence of impact on fish populations is at best circumstantial, usually a decline in fish catches as cormorants increase. In three of four studies, cormorants did not eat the commercial species. In another study, fish catches increased along with cormorant numbers, both trends associated with eutrophication. Six studies have estimated fish consumption by cormorants at 2 to 17% of the standing crop of fish in lakes, and 2 to 10% of the harvest by humans, but none of these studies gave estimates of accuracy.

3.7. On British rivers, six studies of diet have shown that salmonids were rare in cormorants feeding in estuaries, and only occasionally important further upstream. Most of the trout consumed were very small, and salmon smolts were only important on one northern river. Three studies have investigated smolt predation by cormorants. In one of these, smolt consumption was insignificant, in another there was little impact on the fishery and in the third the estimated losses, though high, were unfortunately based on poor dietary information. There is no documented case of cormorants congregating to feed on untagged wild smolts.

3.8. On large rivers in Switzerland, there is conflicting evidence of an effect of cormorant predation on stocked grayling. On the River Ribble in England, claims that cormorant predation makes fish less 'catchable' are under investigation but, as yet the evidence remains anecdotal.

Sawbill ducks

3.9. A review of diet and seven case studies suggests predation by sawbill ducks (goosanders and red-breasted mergansers) is not a serious problem at fish farms or on stillwaters. On a few rivers in eastern Canada, Scandinavia and northern Scotland the diet suggests the potential for an effect of sawbill predation on salmonid fisheries. Experiments attempted in eastern Canada have failed to show any effect of duck predation on salmon stocks mainly because of poor experimental design or procedure. One study suggested that any effect of sawbills was small compared with other factors affecting salmon abundance. In Britain no sawbill duck removal experiments have been done.

3.10. Calculations of the effects of sawbill duck predation have produced estimates of up to 35% loss in salmon harvest, but recent work has shown that some of the assumptions are invalid. Sawbill diet and abundance varies from river to river and could be influenced by stock enhancement and some fish-tagging procedures. Most of the juvenile salmonids eaten by sawbills are small fish from the wider parts of the river (mainstem). More knowledge of salmon population dynamics is required to produce an accurate model of the effect of ducks on harvest, and its predictions will need to be tested.

4. Legal protection in Great Britain and Europe

4.1. Cormorants, goosanders and mergansers are fully protected in Great Britain under the 1981 Wildlife and Countryside Act which implements the European Community Directive on the Conservation of Wild Birds. The Act makes provision for the killing of birds by licenced shooting *"for the purposes of preventing serious damage to .... fisheries"* where no other satisfactory solution can be found. A further clause provides a mitigating defence for the unlicensed shooting of birds under the same conditions.

In Scotland and England licences to kill cormorants and sawbills to prevent serious damage to fisheries have been issued with the presumption that the consumption of large numbers of stocked fish, or juvenile salmonids results in serious damage to a fishery. In addition, some licences to kill birds for scientific purposes have been issued in Scotland to investigate diet.

4.2. Elsewhere in Europe, cormorants and sawbills are similarly protected except by derogation (European Community), or where they are deemed quarry species for hunting. Wherever and whenever the birds are protected, there is usually provision for killing or compensation in circumstances where there is damage, but no countries have specified criteria for assessing damage.

5. Criteria for serious damage

5.1. For the present, *ecological* damage by fish-eating birds remains an academic issue.It is argued that *economic* damage to a fishery by fish-eating birds be quantified in terms of measured losses, and its seriousness judged against local economic circumstances. However, to justify a licence to kill birds, not only has serious damage to be established on the basis of measured losses, but also these losses have to be shown to be the result of bird predation.

5.2. The only way to unequivocally demonstrate an impact of bird predation on fisheries is by experiment. At present licences are issued on the basis of anecdotal and circumstantial evidence which is an inherently unsound procedure. Nevertheless it is impractical for every fishery with a potential bird problem to do an experiment. The most efficient way to proceed might be to experiment in a variety of sites to establish the circumstances in which bird predation could result in serious damage. Thereafter individual cases could be assessed by analogy.

5.3. Given that there may well be circumstances where serious damage by birds occurs, there remains the issue of whether licenced killing can effectively prevent such damage. Again the issue is best tackled by direct experimentation.

6. Suggestions for future NRA policy and research

6.1. Policy with respect to applications for licensed killing

The 1992 NRA position statement on cormorants and sawbills shows that the Authority is fully aware of the concerns of fishing interests, but that in fulfilling its duty to further conservation, and consistent with the Wildlife and Countryside Act 1981, it cannot support shooting birds as a control measure unless serious damage to specific fisheries is proven and other deterrent methods have failed. In the absence of substantiated evidence that the killing of fish-eating birds prevents serious damage to fisheries, it is recommended that there be no change in the current NRA position until such evidence accrues.

6.2. Recommendations for future research

Because the existing NRA position on shooting fish eating birds cannot justifiably be changed without new information, it is recommended that future research proceed in one of three ways:
(i) initiating no new data collection, examining each case as it arises in liaison with the licensing authority, and relying upon fishery interests and the licensing authority to do research to substantiate serious damage to the fishery.
(ii) monitoring bird and fish populations in anticipation of bird problems and investigating individual cases as far as is possible as they arise.
(iii) initiating experimental research work in anticipation of satisfactorily resolving many perceived bird problems satisfactorily.
All three options have advantages and disadvantages and a major factor is whether the available resources are sufficient to initiate or promote experimental research.We recommend option three.

6.2.1. Experimental research

Two questions require answers: does bird predation have a *measurable* impact on fish stocks ? and if so, what mechanisms are the most cost-effective in *reducing* this impact ?

Six experiments should take priority:

(i) the effect of scaring techniques in reducing the number of cormorants using a site.

ii) the effect of shooting in enhancing 'non-destructive' scaring techniques.

iii) the effect of changing stocking regime (varying stocking density or adding 'low value' buffer fish) on the numbers of cormorants using a site.

(iv) the effect of reducing cormorant predation on fish abundance and harvest at a small 'put-and-take' fishery.

(v) the effect of reducing cormorant predation on catches of coarse fish on rivers.

(vi) the effect of reducing cormorant predation on smolt output and adult harvest, on a salmonid river where there is no artificial stocking.

It is suggested that the costs of research be shared between the licensing authorities, the NRA, fisheries interests and nature conservation organisations.

6.2.2. Other research and monitoring

In anticipation of bird predation problems some financial support might be directed towards institutes, university research departments or national research and monitoring organisations to:

(i) investigate cormorant subspecies, diet, choice of foraging site and diving ecology.

(ii) study sawbill movements in relation to food availability, bird density and scaring or killing.

(iii) monitor fish and bird populations, their abundance, fecundity, mortality and movements.

1. INTRODUCTION

In Britain, many birds eat fish in freshwaters. The commonest of these piscivores are great-crested grebe *Podiceps cristatus*, little grebe *Tachybaptus ruficollis*, cormorant *Phalacrocorax carbo*, grey heron *Ardea cinerea*, red-breasted merganser *Mergus serrator*, goosander *M. merganser*, kingfisher *Alcedo atthis* , common tern *Sterna hirundo* and various gulls *Larus* spp. Some of these species live at relatively low densities, or take only small fish and so are considered innocuous. Others are sometimes considered a nuisance in specific circumstances where fish are concentrated or are particularly vulnerable to predation. In such cases fish may be predisposed to predation as a result of artificial circumstances.

For example, divers *Gavia*, cormorants, terns *Hydropogne* and *Sterna*, gulls *Larus*, (and other seabirds) have been recorded consuming many salmonid smolts, but only where there were large scale releases of hatchery fish (eg Bayer 1986) or where smolt were fin-clipped or fin-tagged (Mills 1964, Soikkeli 1973, Valle 1985, Reitan, Hvidsten & Hansen 1987, Montevecci, Cairns & Birt 1988), procedures which can severely incapacitate some fish (Hansen 1988, Kennedy, Strange & Johnston 1991, Isaksson & Bergman 1978, Berg & Berg 1990). Ducks and gulls can take disorientated or damaged fish from the vicinity of weirs or dams (eg Timken & Anderson 1969, Ruggerone 1986) and ducks, crows *Corvus*, Osprey *Pandion*, and herons can consume or damage fish at poorly protected hatcheries, fish ponds or floating cages (Cadbury & Fitzherberg-Brockholes 1984, Draulans & van Vessem 1985, Dawson 1986, Parkhurst, Brooks & Arnold 1992, Carss 1993).

Many such problems can be solved with simple protective mechanisms (Meyer 1981, Carss 1990a) but not if extensive water bodies are involved. Within this context, three bird species, cormorant, red-breasted merganser and goosander, are commonly perceived to present problems for freshwater fisheries in Britain.

Complaints, which often relate to specific times and places, are of three main types: -

i) cormorants eat large fish so that there are fewer available to be caught by fishermen;

ii) all three bird species eat so many juvenile fish that there are subsequently fewer large fish to be caught; and

iii) there are indirect behavioural effects; persistent predation by birds in one habitat or area displaces fish to another where, though free from predation, they are less able to feed and grow, or are less easily caught.

No study has demonstrated unequivocally that avian piscivore activity in Britain has reduced the harvest of wild fish, or angling success. However, in theory such effects are possible so all the evidence needs to be examined with a view to planning studies that could establish and quantify any such impacts.

To this end, this report :-

i) reviews existing information on the current status, foraging ecology, and population biology of the three bird species as background to their potential impact on fisheries;

ii) discusses fish population dynamics within the context of predation effects;

iii) reviews existing experimental evidence for impacts on fish populations and fisheries; and

iv) describes current legislation, discusses potential criteria for serious damage to a fishery, and suggests ways forward for NRA policy and research.

2. SPECIES REVIEWS

2.1. Cormorant

2.1.1. Species and subspecies

Cormorants (and shags) *Phalacrocorax* spp. are long-necked, pursuit-diving (Ashmole 1971) birds. There are about 28 species, living mainly in tropical and temperate zones. Cormorants in Britain and Continental Europe are of the largest (*ca* 2 kg) species *P. carbo*, which has a world wide distribution and includes two subspecies in Europe and others in North America, Africa and Australasia (Cramp and Simmons 1977). The nominate race *P. carbo carbo*, breeds around the North Atlantic, the North Sea, and the White Sea, including the coasts of eastern Canada, Britain, Iceland, Faeroes, Norway, Finland and northern Russia. The other European subspecies is *P.c.sinensis* which breeds around both marine and freshwater areas, south and east of the Baltic Sea and the North Sea.

Formerly, clear distinctions between these two subspecies were documented (recently reviewed in Alstrom 1985, and in Sellers 1993, but see also, Stokoe 1958). There are differences in average size and appearance, most *sinensis* being slightly smaller than most *carbo*, with a green rather than purple gloss to the plumage, a greater preponderance of white in the breeding plumes of thigh and nape and apparently, a differently shaped gular pouch. *Carbo* is mainly coastal (breeding on rocks and cliffs) and said to be largely resident, using coastal waters and some freshwaters in the milder parts of its range in winter. *Sinensis* is more migratory, a summer visitor to the freshwaters of Central and Eastern Europe (breeding in trees) and has a correspondingly different pattern of post juvenile moult (Hald-Mortensen, in press). As European cormorant populations have increased over the last 20 years, the distinctions between the two subspecies seem less well defined. In France a population of coastal breeding cormorants is apparently intermediate in appearance between *carbo* and *sinensis* (Debout, in press), whilst some inland breeding populations resemble *sinensis* but are less migratory than those breeding further north and east (Marion 1983). There is now also good evidence, from both the movements of colour-ringed birds and the superficial appearance of breeders, that both subspecies regularly winter in Britain. Birds colour-ringed as nestlings on the continent (*sinensis*) and in Wales (*carbo*) have wintered and bred at Abberton Reservoir, Essex in south-east Britain, in 1993 (G Ekins pers. comm.).

The subspecific status of cormorants in Britain is relevant to their potential conflict with freshwater fisheries here in three ways. Firstly, Britain holds about a third of the world population of *P. c. carbo* (estimate by Sellers 1991) and most of those that breed in the EC, so Britain has a major responsibility for the conservation of this subspecies. Secondly, if more *P. c. sinensis* settle to breed in Britain, introgression between races might produce cormorant populations with an enhanced repertoire of seasonal movements and breeding patterns, able to exploit freshwater fish populations all year round. Finally the subspecies *sinensis* is specially protected as an Annex I species of the EC Birds Directive (Article 4). Such species are "the subject of special conservation measures concerning their habitat in order to ensure (their) survival and reproduction in (their) area of distribution". As birds of the *sinensis* type are increasing in Britain, any measures taken to manage *carbo* will also affect *sinensis* and their designation as Annex I species cannot be ignored.

2.1.2. Diet

Within the context of the impact of fish-eating birds on fisheries, estimates of diet are necessary to discover whether 'commercially' important fish are regularly eaten by birds and, if so, whether such predation is predictable.

The diet of fish-eating birds can be estimated using a variety of methods, all of which have advantages and disadvantages (Marquiss & Leitch 1990, Harris & Wanless 1993, Duffy & Jackson 1986). In general, estimates derived from samples of recently consumed items are subject to least bias and those from well-digested material most bias (eg van Heezik & Seddon 1989). Estimates based on cast oral pellets can be particularly misleading because the remains of some species and sizes of fish are under-represented (Duffy & Laurenson 1983; Johnstone, Harris, Wanless & Graves 1990). An experimental feeding study of cormorants, by Zijlstra (in press) showed only about half of consumed otoliths were recovered in pellets, and these had been reduced in size by digestion leading to an underestimate of the weight of small fish (<10 cm) by 56% compared with an underestimate of 30% for larger fish. Studies using pellets are therefore only useful in a qualitative way, or in comparing the relative frequencies of different items in samples of pellets of varying provenance . Table 1 lists not only the habitat, location and months of dietary studies, but also the methods used.

A large number of European studies of diet (Table 1) show*Phalacrocorax carbo* is almost entirely piscivorous and consistently feeds on relatively few species. At least 77 species of fish are recorded as cormorant prey in Europe but only about a third of these feature regularly, and within habitats different studies have shown similar prey spectra despite differing methods. In the sea, cormorants mainly feed on bottom-dwelling fishes, wrasse and gadoids over rocky and weed covered substrates, flatfish over soft substrates and eel and eelpout in a variety of areas. On occasions small, shoaling, midwater fishes such as clupeids, capelin and even sandeels, are also taken. In estuaries, flounder, trout, eel and saithe are most frequent prey, and sandsmelt, mullet and sea bass are important in the south. On rivers, diet varies according to stream characteristics. Trout, salmon and grayling are the main prey in fast-flowing sections, cyprinids (roach and bream) in slower, deeper parts and flounder in the lowest reaches. In studies at freshwater lakes, by far the commonest recorded prey are roach, perch and eel. Other cyprinid prey in 'rich' freshwaters include bream, rudd and tench, and other percids, notably ruffe and zander. In more 'acid' and/or species-poor waters, cormorants feed mainly on brown trout or perch. Finally, cormorants frequently use waters artificially stocked for recreational angling (brown and rainbow trout) as well as carp farm ponds. Even where farmed fish are confined within suspended cages, escaped rainbow trout congregate to feed from faeces and waste food and are then sometimes taken by cormorants.

Within habitats and locations the species composition of the diet can vary from year to year, from month to month and even from day to day. It has been argued that weather affects the diet in the short term, as for example the proportion of eel increased in association with warm weather (van Dobben 1952). Seasonal shifts in the importance of particular species are common. In species-rich standing waters in Europe, there is a tendency for some cyprinids (mainly roach or bream) to predominate in the diet in early spring, followed by ruffe, then often eel in summer, and switching to perch or zander later in the year (van Dobben 1952, Marteijn & Dirksen 1991, Veldkamp 1991, Suter 1991a). There also seems to be seasonal tendencies for some other species as, for example, large grayling are taken on rivers in late winter and early spring in several countries (Suter 1991a, Keller in press, Carss & Marquiss in press).

With such generalisations, it is tempting to argue that cormorant diet is predictable according to habitat and season (as is apparently the case in Switzerland; Suter in press a), but this could only be done accurately where the fish community (potential prey) is quantified. There are well documented instances where a change in the diet at a specific site has been associated with changes in the abundance of some prey. At one site in the Netherlands, the eutrophication of lakes was associated with increased abundance of cyprinids, and the diet of cormorants at a nearby colony changed as eel and ruffe became less important and roach, bream, silver bream and rudd became more so (Veldkamp 1991). Artificial enhancement of some fish populations has also given circumstantial evidence of dietary switches following changes in the relative abundance of alternative prey. At Loch Leven in Scotland, the diet of cormorants switched from predominantly perch, to predominantly trout following the release of substantial numbers of hatchery-reared trout (Carss & Marquiss 1992). On the River Bush in Northern Ireland, Kennedy and Greer (1988) found cormorants fed exclusively on hatchery-reared salmon smolts downstream from their release point, but on medium-sized trout and some small salmon upstream of it. Only four cormorant stomachs were examined from above the hatchery, and four from below, but the difference was clear.

Table 1. The predominant prey fish (estimated >10% by mass) in dietary studies of cormorants in Europe. Methods: stomachs of dead birds (S), regurgitates from nestlings (R), pellets (P) and visual observations of prey consumed on the surface (V). Scientific names are in Appendix I.

Habitat	**Location**	**Months**	**Method**	**Prey** (in order of importance)	**Study**
Marine sea coast					
	SW England	X-II	S	flounder, plaice, dab.	Steven 1933
	E Denmark	IV-VII	S	eel, eelpout, herring, cod.	Madsen & Sparck 1950
	E Denmark	IX-XII	S	eel, cod, eelpout.	Madsen & Sparck 1950
	W Ireland	VIII-X	S	pollack, herring.	Piggins 1959
	NE England	VI,XI	R/S	flatfish, gadoids, eel.	Pearson 1968
	E Scotland	VI-VII	R/P	dab, saithe, eelpout.	Mills 1969
	E Scotland	VIII-XII	S	flatfish, gadoids, clupeids.	Rae 1969
	Ireland	VI	R	wrasse, eel, flatfish.	West *et al* 1975
	W Sweden	VI	P	wrasse (3 spp), cod.	Harkonen 1988
	E Denmark	V-IX	P	dab, eelpout, cod.	Harkonen 1988
	E Finnmark	VII	P	gadoids, capelin.	Barrett *et al* 1990
	W Norway	VII	P	gadoids	Barrett *et al* 1990
	W Norway	IX-X	P	gadoids	Barrett *et al* 1990
	W Russia	IV-VIII	P	gadoids, clupeids.	Blanki *et al* *
	N Germany	VIII,IX	V	eelpout	Kieckbusch 1993
Estuary					
	W Ireland	V-VII	S	brown trout, eel.	Piggins 1959
	Scotland	?	S	flounder, sea trout	Mills 1965
	NE Scotland	IX-VI	S	flounder, saithe.	Rae 1969
	SE England	IV-VII	R	eel, flatfish, garfish.	Carss & Ekins unpub.
	N Italy	X-II	P	sand smelt, mullet, sea bass.	Boldreghini *et al* *
	Central Italy	X-II	P	mullet.	Martucci & Giovacchini*
Rivers					
	Scotland	?	S	trout, salmon, flounder.	Mills 1965
	SE Scotland	XI-III	S	grayling, roach, salmonids, flounder.	McIntosh 1978
	N Ireland	V	S	brown trout, salmon.	Kennedy & Greer 1988
	Switzerland	X-III	P	grayling, brown trout.	Suter 1991a
	SW Scotland	III-IV	S	flounder, trout, roach, perch.	Carss & Marquiss *
	SE Scotland	II-IV	S	grayling, trout.	Carss & Marquiss *

Table 1. (continued)

Rivers (continued)				
N Scotland	IV-V	S	salmon, trout.	Carss & Marquiss *
Netherlands	IX-III	P	bream, white bream.	Noordhuis *et al* *
Impounded river				
Switzerland	X-III	P	roach, chub.	Suter 1991a
Freshwater lakes and lochs				
NW England	XI-III	S	char, perch, brown trout.	Hartley 1948
Netherlands	III-VII	R	roach, eel, ruffe, zander, bream.	van Dobben 1952
Scotland	?	S	brown trout, perch, salmon.	Mills 1965
Netherlands	IV-VII	R	bream, eel, zander.	De Boer 1972
Ireland	IX-IV	P	roach, perch.	Macdonald 1987
Netherlands	IV-VII	P	ruffe, smelt.	Voslamber 1988
N Germany	VII-XI	P	perch.	Worthmann & Spratte1990
Netherlands	X-III	P	ruffe, perch, zander, cyprinids.	Marteijn & Dirksen 1991
Switzerland	X-III	P	roach, perch.	Suter 1991a
Netherlands	III-VII	R	roach, bream, eel.	Veldkamp 1991
NE Poland	IV	S	roach, eel, tench, bream, pike.	Mellin & Martyniak 1991
NE Poland	IV-VII	P	roach, eel, perch, bream.	Mellin & Martyniak 1991
S Germany	XI-II	P	roach, rudd.	Keller *
E Scotland	X-III	S	perch, brown trout.	Allison unpub.(L. Leven prior to stocking).
Stocked lochs				
Scotland	III	S	rainbow trout	Carss & Marquiss (unpub)
E Scotland	I-III	S	trout.	Carss & Marquiss * (L. Leven post stocking)
Fish farm ponds				
S France		?	carp.	Im & Hafner 1984
Netherlands		?	carp, grass carp.	Moerbeek *et al* 1987
NE Poland		S/P	carp.	Mellin *et al* *
Fish farm cages				
W Scotland	IX-III	S	rainbow trout (escapees)	Carss 1993

* papers from the cormorant conference, Gdansk, 13-17th April 1993 - proceedings in press.

The fish consumed by cormorants vary enormously in size. Stomachs from Scottish rivers for example have contained tiny sticklebacks, as well as a very large 'mended' kelt of 1.53 kg (Carss & Marquiss in press). The range of sizes of fish taken by cormorants, for a variety of prey species, are given in Table 2 alongside estimates of the most common sizes from various dietary studies. Within some prey species or groups (eg eel, trout, roach and flatfish) there are similarities in the range of sizes taken in different habitats, but this does not apply to the size of average fish taken which varies between studies of the same habitat, as well as between habitats.

Some of this variation could be attributable to the varying methods used, because prey remains from pellets can underestimate the length of ingested fish. However, some workers have sampled the same site systematically and have found size variation between months (ruffe; Marteijn & Dirksen in press) and between successive years (ruffe and zander; van Dobben 1952), consistent with the idea that the birds were eating one particular age cohort of fish. Thus, as with the species composition of the diet, the sizes of fish taken are not easily predictable, particularly in the absence of accurate fish community data.

Table 2. The sizes (cm) of fish recorded in dietary studies (references given in Table 1.) of cormorants in Europe.

Habitat	**Fish species**	**Range of recorded sizes** (smallest - largest)	**Most common sizes**(means, medians or modes; various studies)
Sea coast	eel	10-65	23,26,40
	herring	7-18	-
	gadoids	3-35	15-18
	eelpout	-	20
	wrasse	10-38	19,29
	sandeel	6-12	8
	flatfish	7-21	11,14,18
Estuary	eel	14-56	18
	salmon	11-13	10
	trout	10-26	17
	flounder	7-18	8
River	salmon	6-16	9,10,11,13
	trout	7-47	10,15,18
	grayling	23-40	26,38
	roach	4-26	12
	flounder	7-17	12
Lake	eel	12-60	19-25,25,33,37
	trout	13-46	25,25
	char	-	25-30
	smelt	4-10	7-8
	pike	13-42	-
	perch	3-30	5,7,8,10,14,15,15,17,20
	ruffe	3-19	6,8,11
	zander	7-37	8,17,26
	tench	13-36	23,26,32
	bream	5-33	14,14,14,18,23,25,
	roach	5-30	8,9,13,14,14
Stocked lake	trout	6-45	25
Pond farm	carp	-	8-11
Cage farm	rainbow trout	15-31	22

2.1.3. Foraging behaviour

The largest of the cormorant species, *carbo* has the ability to dive for longer, and possibly deeper, than others (Cooper 1986). A stout, hooked bill enables the seizure, maiming and often killing, of very large fish (Takashima & Niima 1957, Carss 1990) prior to their being manipulated and swallowed head first (Reimchen 1991). The prolonged handling time involved means such instances are frequently observed and the literature is full of 'cormorants with big fish' stories (eg St John 1882, Snook 1991) even though most fish consumed by cormorants are much smaller (Table 2). As with other fish-eating bird species (eg pelicans, Brandt 1984; herons, Quinney & Smith 1980; terns, Dunn 1972) a cormorant's skill in catching fish efficiently is probably learned through experience. Juvenile cormorants do not achieve the foraging success rate of adults until they are well into their first winter; although they acquire the diving ability of adults soon after fledging, they have a lower capture success and apparently forage for longer in the day to compensate (Morrison, Slack & Shanley 1978).

In many studies (eg Steven 1933, Madsen & Sparck 1950, Harkonen 1988, Veldkamp 1991) the diet of mainly bottom-dwelling fishes suggests that cormorants catch much of their prey there, but other studies (eg Suter 1991a, Voslamber & van Eerden 1991) emphasise the importance of mid-water shoaling fishes. There is an association between habitat, diet and foraging behaviour. Cormorants feed solitarily on bottom-dwelling fishes, but social groups (sometimes involving 1000's of birds) can congregate to feed on on large shoals of small fish in mid-water habitats (Suter in press b; Kiekbusch & Koop in press) or in shallow, often turbid, waters with flat bottoms where there is little in the way of cover (macrophytes or crevices) to offer refuge (Voslamber & van Eerden 1991). The latter authors argued that the sequential diving pattern of the flock sustained the pursuit of the fish shoal, temporarily exhausting the smallest fish which could then be seized. Such social fishing requires large aggregations of cormorants. It is currently a common phenomenon in the Ijsselmeer, Netherlands, and has been described on lake Malawi (Linn and Campbell 1992), but to date it has probably rarely occurred in British waters because this conspicuous behaviour has not been documented in the past. D N Carss and G Ekins (in prep) describe an instance in summer 1993 where 40-50 cormorants were apparently collectively feeding on roach fry on Abberton reservoir in Essex. Also in 1993 H Kruuk (pers comm) saw cormorant flock-feeding off the Shetland sea coast in November.

The diet of cormorants varies not only with their choice of foraging habitat and feeding method, but also with location. Cormorants can commute very large distances to fish; up to 70 km from roosting sites (Suter 1991b) and 35 km from the breeding colony (Platteeuw 1991). The latter study calculated time and energy constraints on the length of foraging trips, particularly under adverse flying conditions (high winds), but the distances involved illustrate the mobility of cormorants which often allows a wide choice of foraging areas on a daily basis.

In theory, cormorants thus have a repertoire of feeding options with which to optimise their food intake but in practice it is difficult to demonstrate optimality in foraging. Some studies of cormorant diet argue that cormorants forage opportunistically, taking the most abundant and easily caught prey (eg Trayler, Brothers, Wooller, & Potter 1989) but this is difficult to demonstrate because fish availability can rarely be estimated accurately; in most studies it is merely implied, retrospectively. Similarly several studies suggest that cormorants select fish of particular sizes, yet such claims are rarely based upon adequate data. It seems obvious that size-selection takes place bearing in mind the predominance of certain size classes (Table 2). However to demonstrate this properly, diet needs to be estimated from large samples of relatively undigested material, and compared with prey populations that have been quantified accurately. Marteijn & Dirksen (1991) tried to demonstrate size selection by comparing estimates of diet from the contents of pellets, with estimates of fish populations from trawl and seine net catches, but their case demanded complicated argument and some unsubstantiated assumptions. Selection by cormorants is relatively easy to show in their use of fish ponds holding stock of differing size (Osieck 1981), but most of the 'natural' habitats offering a variety of fish species and sizes for cormorants, are not easily sampled to quantify fish community populations.

There is some indirect evidence of cormorants selecting foraging habitats preferentially, in that as the wintering population of Switzerland grew, bird numbers increased first on large eutrophic lakes, then on other lakes, rivers and dams and finally on smaller lakes (Suter 1989). The implication was that the birds preferred the first occupied habitats, presumably because fish were more available there. Seasonal patterns of habitat switching in Britain, from the coast to lakes, then rivers (Feare 1987, Starling *et al* 1992) could also be explained by cormorants tracking fish availability. Such behaviour has important implications for predicting the use of sites by cormorants, and for any attempts at managing cormorant populations.

2.1.4. The amount of fish consumed by cormorants

Diet is only one element used in modelling the potential impact of cormorants on fisheries. To estimate the consumption of fish by cormorants also requires estimates of the numbers of birds concerned and their food intake rate. Four methods have been used to estimate the daily food intake of individual birds:-

(i) The daily requirement of captive birds is measured by averaging the weight of fish consumed over a series of days. Such estimates will tend to underestimate the intake of wild birds which expend more energy (in foraging, commuting and reproduction) and therefore require more fish.

(ii) The daily ration for wild birds is calculated from the undigested remains in oral pellets which are cast once a day. It is assumed that all dietary items are represented by at least some remains, and that the size (and therefore the weight) of dietary items can be calculated accurately. However, as previously discussed, feeding experiments with captive cormorants show that these assumptions are invalid (Zijlstra, in press).

(iii) The daily ration for wild birds is assumed to be equal to the contents of full stomachs. The main problem with this method is in defining a full stomach. Taking only values from the fullest of stomachs may overestimate daily ration as there will be a bias towards birds that have eaten more than their daily requirement, and against those that have eaten less.

(iv) The theoretical intake is estimated based on calculations of the daily energy demand. This is done by scaling up the basic metabolic rate (BMR) measured in a respirometer or derived from allometric equations relating BMR to body size. The calculation is done on the basis of the behavioural time budget of the bird; estimates of the energetic cost of flying, diving, sleeping etc, being multiplied by the time estimated to be spent by birds on these various activities. The main problem with this method is that it involves complicated calculations with figures that are sometimes of unknown accuracy. It is difficult to time budget the behaviour of wild birds, and very difficult to cost the energy expended on specific activities. The total energy used over a period of time can be estimated more directly using doubly-labelled water (D_2O^{18}) to work out the turn over of hydrogen and oxygen in the body, but we can find no published reference to this method being used on cormorants.

Various studies that have estimated daily food intake (Table 3) and these have produced figures of 6-32% of the bird's body weight of fish per day. As expected, some very low figures have been derived from the contents of pellets and the highest figure comes from a study of full stomachs. Figures from the measured intake of captives are probably on the low side (12-20%) and a more realistic figure probably lies between those estimated from energetics calculations (17-26%). This represents a daily intake of between 340 g and 520 g.

Table 3. Estimates of the daily food intake of cormorants, from studies using various methods.

Study	Method	Intake (% body weight)
Serventy 1938	Captives (full grown)	17
Madsen & Sparck 1950	Captives	20
Junor 1972	Captives	16
Sato, Hwang-Bo & Okumura 1988	Captives	15 ±4 (SE)
van Dobben 1952	Captive chicks (growing)	20
Junor 1972	Captive chicks	18
van Dobben 1952	Complete meals regurgitated (1938)	16 ±1 (SE)
	(1939)	20 ±1 (SE)
Rae 1969	Full stomachs	17
McIntosh 1978	Full stomachs	32
van Dobben 1952	Pellets	15
Voslamber 1988	Pellets	12-18
Marteijn & Dirksen 1991	Pellets	15-21
Keller *	Pellets	14
Martyniack *et al* *	Pellets	6-11
"	Pellets	7-17
Voslamber 1988	Energy demand calculation	17
Sato *et al* 1988	Energy demand calculation	26

* Gdansk Cormorant Conference, April 1993, (proceedings in press).

2.1.5. Population trends in Europe and Great Britain: changes in numbers and distribution

2.1.5.1. Counting methods

Cormorants aggregate to breed in groups of ten to thousands of nests and their populations are most often estimated by counting the numbers of occupied nests in colonies. There are some problems with this method. For example, there are minor difficulties in classifying some nests as occupied or unoccupied, and deciding whether late nests represent new pairs or pairs laying again following a first attempt. More importantly if, like grey herons, cormorants sometimes switch breeding sites between years (indirect evidence - Rov, in press), there arises a problem of birds using novel sites to form a new colony which can remain undetected (and uncounted) for a few years until the colony is registered. This is less of a problem where cormorants breed in large protected colonies which persist in the same area for decades. In such colonies, careful observations and repeated systematic counts should give good estimates of the numbers of breeders and trends from year to year, although we can find no attempt in the literature to assess the accuracy of such monitoring, as has been done for some seabirds (eg Rothery, Wanless & Harris 1988) and grey heron populations (Marquiss 1989). Finally, there is also a problem in the interpretation of counts at breeding sites as some drops in colony nest counts could, in theory, be the result of some adult cormorants failing to attempt to breed in some years. Counts of wintering birds are usually accomplished by systematic coordinated counts from a sample (sometimes from most if not all) of roost sites and feeding sites. Again, accuracy is rarely estimated (but see Starling *et al* 1992).

None of these problems are of great significance at present because European cormorant populations have increased consistently and substantially in recent years. Good estimates of accuracy become critical when there is debate over population size and trends, or where there is a need to estimate (with confidence intervals) the amount of fish consumed by cormorants. With this in mind, counters need to standardise counting methods used for specific purposes, trading off accuracy against 'cost' for various methods according to purpose.

2.1.5.2. Changes in *sinensis* populations

The population of *sinensis* breeding in some countries has been counted for over 50 years, and has apparently increased exponentially to its 1992 level of about 105,000 pairs (an estimate given at the 1993 Gdansk conference). The population at the turn of the century was said to be low because of the persecution of breeding birds. Following the protection of some breeding sites there was an increase in the Netherlands, but this increase was apparently curtailed from the late 1940s until the mid 1970s from when the population began a major expansion. There were parallel increases elsewhere in Europe with expansion of the breeding range southwards and eastwards (eg Latvia, Baumanis; Ukraine, Gorban & Bokotej;.Lithuania, Jusys;

Byelorussia, Samusenko - all in press). The estimates of average rates of population increase varied between 11 and 37% with a median value of 22% per annum (Table 4). A study by Suter (1989) summing counts of cormorants from studies published at that time, estimated the average rate of increase of the whole North Central European population to be 21% per annum. There have been equivalent population increases in the wintering areas; in Switzerland, France and Italy (Table 4).

2.1.5.3. Changes in *carbo* breeding populations

In contrast to *sinensis*, *carbo* populations have not increased so dramatically. There has apparently been sustained increase at some colonies of the White Sea population (Bianki, Boiko & Kokhanov, in press) but the East Finnmark population has fluctuated (Rov , in press). The same author records an increase in Central Norway. In Britain and Ireland the population has probably declined in North West Scotland, but increased elsewhere (3% per annum overall, Sellers 1991, and in Gibbons *et al* 1993), particularly in Ireland where the average increase between 1969/70 and 1985/6 was about 6% per annum (data from Macdonald 1987). Note however, that even an increase of this magnitude was modest by comparison with changes in *sinensis* populations. The population of Northern France (probably *carbo* ssp.) has also shown only modest increases of 3% per annum up to 1960 and about 9% thereafter. The situation there is complicated because recent increases (11%) are mainly in inland breeding colonies which could be of *sinensis* provenance (Marion 1991). The most recent published estimate of the European *carbo* breeding population was about 36,000 pairs for 1988/9 (stated in Sellers 1991), of which about 12,300 were in Britain and Ireland (estimate for 1987). In the New Atlas of Breeding Birds (Gibbons *et al* 1993) the same author gives figures of about 7,000 pairs for Britain (excluding inland colonies) and 4,700 for Ireland. Some figures presented at the 1993 conference suggest a total European *carbo* breeding population of about 40,700 pairs in 1992. This however assumes that the increase in the population of Britain and Ireland has been sustained with a current (1992) estimate of 14,000 pairs. In the absence of comprehensive census these figures are necessarily speculative and of unknown accuracy.

2.1.5.4. Wintering *carbo* populations

In winter some *carbo* cormorants from the far north of Europe apparently move southwards into the Baltic, Kattegat and Skaggerak. Many British cormorants are resident, wintering locally along the coast and some inland. Ring recoveries are heavily biased towards localities where birds are shot but nevertheless suggest that birds from different colonies could have colony-specific wintering areas (Coulson & Brazendale 1968, Summers and Laing 1990). The median distance from the natal colony that birds were shot in winter varied and the main factor involved was thought to be the reluctance of cormorants to cross large expanses of open sea.

Table 4. The average rates of increase in post 1960 counts of *sinensis* cormorants in Europe, at breeding colonies, and on the wintering grounds. Estimates calculated from data presented at the 1989 & 1993 cormorant conferences.

Region	Period	% increase per annum	Authors
Breeding colony counts			
Sweden	1980-1986	18	Lindell
	1986-1989	34	"
	1989-1992	24	"
Denmark	1981-1992	22	Gregerson
Netherlands	1960-1988	22	Zijlstra & van Eerden
GDR	1980-1988	26	Zimmermann & Rutschke
FRG	1977-1988	37	Menke
Poland	1981-1988	20	Gromodzka, Przybysz J, Mellin
	1988-1992	14	Przybysz A & Mirowska-Ibron.
France	1981-1988	11	Marion
Ukraine (Danube)	1984-1992	30	Zhmud & Chorny
(Dnister delta)	1976-1992	22	Shchegolev, Rusev & Korzyukov
Roumanian Danube	1980-1992	14	Gogu-Bagdan
Winter counts			
Switzerland	1967-1979	10	Suter
	1979-1987	28	"
France	1983-1992	19	Marion
Italy	1980-1988	23	Baccetti
	1988-1992	22	Boldreghini, Cherubini, Santolini, Utmar & Volponi

Many cormorants from colonies in England and Wales previously wintered along the French and Iberian coastline but there have been changes in the patterns of recovery of ringed birds (Sellers 1991) that suggest more birds now winter in Southeast England; some on the coast but increasingly more on inland freshwaters. Marion (1991) suggested the increasing numbers of *sinensis* cormorants wintering in France have effected this change through competition, but a more plausible argument (Sellers 1991) is that there has been an increase in fish-stocked freshwaters in southeast England, so British birds do not have to travel so far from their natal site to survive the winter.

The numbers of cormorants wintering in Britain and Ireland have only recently been estimated by a winter census in 1985/86 (detailed in Macdonald 1987, Porter 1987 and Feare 1987). In that winter there were about 23,400 birds, mostly on the coast but with about 5,500 inland. Only a few hundreds were counted inland in Scotland and Wales; most (ca 4,000) were in England, principally concentrated in the southeast (see map, fig 4 in Feare 1987). The most recent estimate of the numbers of cormorants wintering in England, Wales & Scotland was 16,800 in 1990 (Starling *et al* 1992), about 24% more than the estimate of 13,500 for the same area (though not using identical counting sites) in 1985/6, and representing an average annual increase of about 4%. These figures compare well with the trends in numbers of breeding birds, consistent with the idea that most wintering birds are from British and Irish colonies. Some in Southeast England are known from their colour-rings to be from *sinensis* colonies (G Ekins in press) and even some birds in Scotland are so small as to resemble *sinensis* (Carss & Marquiss unpublished). However, such individuals are apparently, as yet, in the minority.

Annual monitoring of the wintering population using National Waterfowl Counts started in 1986/87 but there have been counts at some specific sites since the 60s (Sellers 1991, Kirby & Sellers in press). There have been increases in counts in most parts of Britain, the main exceptions being northeast Scotland and north Cumbria / southwest Scotland (Starling *et al* 1992). For some sites, counted in every winter, there has been an increase of 18% per annum from 1986/7 to 1990/91. Sellers (1991) gave a longer series of data from two sites suggesting this level of increase since the late 60s - 17% for Greater London and 16% for the Severn Estuary. At first glance this level of increase seems to be at odds with the estimate of 3% per annum for the breeding population, but this latter figure includes Scottish breeding colonies where there has been a decline. Cormorant colonies in southern Britain have sustained higher increases, with an exceptional level of just over 40% per annum in the case of the inland site at Abberton from 1981 to 1993 (Ekins *in lit.*).

2.1.6. Factors influencing population change

Three factors have been suggested as effecting the dramatic increase in the *sinensis* cormorant population; a reduction in the killing of cormorants by man, a reduction in the detrimental influence of environmental pollutants, and an increase in the cormorants' food supply (Zijlstra

& van Eerden 1991, Gregersen 1991a, Suter 1991a). With the capability of regularly producing up to 2.6 young per nest (van Eerden, Zijlstra and Munstermann 1991), and with an adult mortality rate of 7-14% per annum (Kortlandt 1942), it is not surprising that population growth can sustain an average of 21% per annum. The debate is therefore whether an enhanced production of young or the increased survival of full grown birds has contributed most to population growth, and whether these parameters are mainly affected by food supply, pollutants or persecution.

It is frequently stated that populations of cormorants in Europe were low early this century because they were killed, exploited and harassed at their breeding colonies. The evidence for this is that populations were low, and stayed low whilst birds were killed in large numbers, but that the population increased immediately following on the cessation of such killing; eg 1965 in the Netherlands (Zijlstra & van Eerden 1991) and 1972 in Denmark (Gregersen 1991a).

However, it was also during this period that pollutant levels were changing. Dirksen *et al* (1991) give correlative evidence that persistent organochlorine pollutants reduce the breeding success of cormorants mainly by reducing hatching success. Koeman *et al* (1973) found such high levels in cormorants found dead in 1970 and 1971, that it was thought these birds had died of PCB poisoning. It is therefore feasible that such pollutants had an effect on both breeding production and adult survival, perhaps contributing to the very low population in the late 1950s and the 1960s; the years of most intensive use of these chemicals in western Europe (reviewed in Newton 1979).

At the same time as organochlorine levels were declining, nitrate and phosphate run off from liberal agricultural fertiliser application was leading to the eutrophication of freshwaters and corresponding increases in cyprinid and percid fish. In places such as the Ijsselmeer, Netherlands, eutrophication combined with the human exploitation of percids has led to large increases in cyprinids, particularly roach. Also during the 1970s there was an enormous increase in pond fish-farming, over much of Europe. Both roach and farmed carp are heavily exploited by cormorants in summer and winter, and undoubtedly this increased food supply helped fuel the population increase.

Consequently, there is sufficient evidence to suggest that all three factors could have contributed to the population explosion by both increasing production and reducing adult mortality. Unfortunately, although population growth has been well documented, there are no published data quantifying associated changes in breeding success and post-fledging survival rate. It is therefore impossible to weigh up the relative contribution of these two factors to subsequent population growth, let alone distinguish between the specific effects of persecution, pollutants and food supply. It is particularly difficult to get comparative estimates of the mortality of full grown birds because, at different times there were differing proportions of the ring recoveries from birds shot or caught in nets. Recoveries involving human agency heavily bias estimates of mortality (Newton, Marquiss & Rothery 1983). Such recoveries are over-represented in samples from areas where killing is legal, and can be under-represented in samples from areas where it is not. A further complicating issue is that cormorants can live long enough to 'wear out' some of the leg rings of early manufacture, leading to ring loss (Harris 1980) and over-estimates of mortality.

Irrespective of the factors leading to population increase, there is now circumstantial evidence of limits on numbers. The populations of *carbo* breeding in Northern France (Debout 1991) and in Central Norway (Rov in press) show evidence of an upper limit to local numbers correlated with the estimated amount of cormorant foraging habitat (water <10 m in depth) nearby. Also, as the original *sinensis* colony in the Ijsselmeer increased in size there was a levelling off in the annual increment. The population further increased only by the formation of a colony in a new locality which allowed birds to exploit an area of water previously distant from a breeding site. The initial rate of increase at this colony was so large that it implied the recruitment of a number of 'mature' birds. This in turn suggested that the foraging area around the original colony had become fully used and the vicinity of the second colony had previously been exploited by nonbreeding birds. The process was repeated as a third colony started (Zijlstra & van Eerden 1991). There have been similar patterns of colony formation as the population of Denmark increased (Gregersen 1991a).

A similar stepwise sequential use of foraging areas accompanied the growth in the wintering population in Switzerland (Suter 1989, 1991a). The original small wintering population used four large mesotrophic-eutrophic lakes and its increase apparently tracked increases in roach and perch populations which accompanied eutrophication. After 1980, a new lake was used and numbers there grew rapidly associated with its highly eutrophic status. By 1987 the population there had levelled and river and dams, then other smaller lakes, were progressively used.

Details of the population dynamics of cormorants in Europe may help explain, and perhaps even predict, population trends in Britain. Organochlorine and heavy metal pollution is not a widespread problem in Scotland so local declines in breeding numbers there could be the result of the hundreds killed at fish farms, stocked lochs and on rivers (Carss in press). It is argued that the overall increase in cormorants in Britain and Ireland is related to its recent legal protection, but as in Europe this factor is difficult to disentangle from increasing food supply. Coastal populations might be expected to have a relatively stable food supply, but overwinter survival of these birds may well have been enhanced in recent years where they winter inland. In Ireland cormorants have exploited the increasing populations of recently introduced roach (Macdonald 1987) and in Scotland and in southeast England, stocked fisheries. It could be predicted that inland wintering populations will rise first, and increase most rapidly, on waters that contain large populations of fish such as cyprinids in eutrophic sites, and trout in stocked sites.

To judge from their diet, the birds at the inland colony at Abberton Reservoir feed mainly on the coast (Carss & Ekins unpublished) and are using a foraging area that has not previously supported breeding birds, at least in the present century. The current phenomenal increase at this colony was thus to be expected. The rates of increase at Abberton, and of wintering populations, are not exceptional by European standards and, by analogy, could continue though not indefinitely. Left alone, the cormorant population of Britain will ultimately stabilise, the total number proportional to the amount of available food, but this process will be prolonged if their food supply continues to be increased artificially.

2.2. Goosander

2.2.1.Species, distribution, habitat, breeding and movements

'Sawbills' are specialised ducks (*Mergus* spp) that feed mainly on fish by pursuit diving. World-wide only the two species, goosander *M. merganser* and red-breasted merganser *M. serrator* , are perceived as potentially damaging to fisheries. Both species have circumpolar distributions that overlap considerably in boreal and low arctic zones, lying between latitudes of 40^{o} and 80^{o} N. In North America the goosander is replaced by a subspecies *Mergus merganser americanus* that is almost identical, but which is called (confusingly for some) the common merganser. Goosanders have stouter beaks and are larger (males weigh about 1.6 kg, and females 1.2 kg) than red-breasted mergansers (males 1.1 kg, and females 0.9 kg). Both species feed on small fishes but red-breasted mergansers forage in more open, sometimes deeper waters, and more often take crustacea (section 2.3.2.).

The goosander is a predominantly freshwater duck rearing young on rivers and sometimes on lakes. Recoveries of ringed birds show northern breeding populations may move south for the winter, though most of those breeding in the southern and western part of the range, particularly in the more oceanic climes, are resident (Boyd 1959, Meek & Little 1977a, Hofer & Marti 1988). Though 'resident', goosanders can move some distance to winter on the lower reaches of rivers, estuaries and freshwater lakes (Owen *et al* 1986), and may move further if freshwaters freeze (Chandler 1981). Changes in the numbers of birds on two rivers in northeast Scotland suggested many had left the catchments to winter elsewhere (Marquiss & Duncan in press a). In Europe there are some very large winter aggregations in shallow brackish waters and large lakes (Ruger, Prentice & Owen 1986). One such flock in Britain, on the Beauly Firth in Scotland, numbered over 1000 birds in the early 1980s (Aspinall & Dennis 1988) but has since declined (Starling *et al* 1992). Outside the breeding season, goosanders gather to roost communally on large standing waters, or on islands and backwaters on rivers. Most birds leave the roost before sunrise and return in late afternoon, near sunset on short midwinter days (Marquiss & Duncan in press b).

By spring, mature goosanders (birds in their second year or older) have paired and move to the upper, faster flowing parts of rivers to breed, the timing related to latitude with birds at the southern end of the range starting to lay in March (northeast Scotland, Marquiss, Feltham & Duncan 1991; Northumberland, S.J.Petty pers comm), but those in the far north, not until May (Lid & Schandy 1984, Hilden 1964, Dementiev & Gladkov 1952). Goosanders lay 7-14 eggs (up to 21 in 'multiple clutches', Marquiss & Cook unpublished) in cavities in trees, cliffs or among boulders and, led by the female, the young leave the nest within 2 days of hatch to feed themselves. Occasionally broods of ducklings will congregate into a creche, but this seems mainly to occur in areas of open water (eg Stutz 1965) where brood density is high or where broods have been harassed (A.J.Erskine, 1971 & pers comm). On two rivers in Northeast Scotland where brood amalgamation was rare, average breeding production varied over 5 years from 3.6 to 0.0 ducklings fledged per spring adult female (Marquiss & Duncan in press a, Carss & Marquiss 1992), and average brood size from 7.4 to 6.1 ducklings per brood. In different years and 10-km sections of river, brood density varied from 0.0 to 0.4 broods per km. A similar range in average brood sizes and brood densities has been found on the river Tweed (Murray 1988, Murray 1992) and on rivers in Wales (Tyler 1986, Griffin 1990).

Once females have commenced incubation, males aggregate once more and migrate north in June to moult in July and August, on estuaries, firths and shallow fjords. In the south of the range, such as in Wales, males can leave the breeding areas as early as April (Tyler 1987) whereas in the north of Scotland they do not leave until late May or early June (Marquiss & Duncan in press a). Adult goosanders become flightless as they moult their wing feathers, and most congregate on expansive areas of shallow open water where they can evade predation by diving but where there is also an abundance of prey. The majority of European males appear to moult in North Norway (Little and Furness 1985) and only a few in Scotland alongside females (Marquiss & Duncan in press a). By late October, fledged juveniles have dispersed and moulted adults return to their wintering areas. Marquiss & Duncan (in press a,b) argue that diurnal and seasonal movement, switching between habitats, is associated with food availability, but also security from predation and the needs of pairing and nesting.

2.2.2. Diet

Sawbill ducks consume at least some of their prey underwater, and it is very difficult to identify prey that is brought to the surface prior to swallowing. Their digestive tract has a gizzard which grinds indigestible material so they do not produce oral pellets and diet has to be estimated from the contents of the foregut. Sawbills are also very difficult to catch so almost all dietary studies (Table 5) have relied upon samples of shot birds. An exception was a study by Heard & Curd (1959) which investigated the stomachs of goosanders killed incidentally by gill nets. Table 5 ranks fish in the diet according to their importance as reported. The various studies are not strictly comparable because some authors merely give counts of various fishes in stomachs whereas others have estimated their size and can thus estimate diet composition in terms of fish biomass. Some authors have ignored all but fairly intact fish which gives a bias towards larger specimens that survive the digestion of soft parts for longer (Marquiss unpublished), whereas other authors have used the presence of particular bones ("key bones", Feltham 1990) which produces less bias. The accuracy of diet estimates have rarely been calculated, most studies merely lumping the contents of all stomachs. This ignores the problem that the contents of a few stomachs might dominate small samples so that the resulting estimate might not accurately reflect the diet of the goosander population at that site and time of year. Estimating the variance between ducks gives very wide confidence intervals even with quite large samples (Feltham, cited in Carss & Marquiss 1992). One way to overcome this problem is to quantify the effect of sample size on estimates of diet by reiterative subsampling from a large sample of ducks (Marquiss & Carss in prep).

The diet of goosanders is diverse, mainly small fish between 5 and 11 cm taken from rivers although slightly fish are taken from lakes (Table 6). In spring they can feed on carrion fish (Rae & Duncan 1989) and frogs can be important then. In summer, small ducklings feed on large insects as well as small fish, and at times adults have been known to take freshwater crayfish.The emphasis on data from shot birds has led to a bias in the published literature towards the diet in places where it was thought they were eating commercial or sporting fishes but it is obvious that in most places at most times of year, goosanders are not eating such fish (Table 5).

On rivers in North America, the main elements of diet are suckers, sculpins, salmonids, shiners and eels, with the inclusion of fallfish and alewife in autumn. Ducklings feed mainly on shiner, with some small salmonids and cottids. The diet on lakes includes a similar array of fish types but also includes 'chub', smelt, yellow perch and killifish in the north. In the warmer waters of the southern lakes and reservoirs, where large congregations of birds spend the winter, the diet is mainly 'forage fishes' - gizzard shad, carp, perch, freshwater drum and white crappie. The birds are feeding on fish of commercial interest in a few instances - in winter, on Washington lakes stocked with hatchery rainbow trout and on Michigan rivers on trout (including stocked brook trout), and in summer and autumn, on a few rivers in New Brunswick and Nova Scotia, they take juvenile Atlantic salmon.

In the the Old World (Palaearctic) the diet is similar - on rivers it includes salmonids, eel, lamprey, bullhead, grayling and perch, ducklings consuming minnows, salmonids and stoneloach. On lakes outside the breeding season, the diet is mainly cyprinid and percid fish and sticklebacks. In winter and spring, in shallow coastal waters, eel, eelpout, stickleback, gobies, sandsmelt, butterfish, cottids and roach are taken. Goosanders fed on fish of commercial interest on only a few northern rivers where they take trout, salmon and arctic char in spring and summer. In general terms, the diet of goosander appears to consist of the most easily caught small fish, of those most abundant in the various habitats used by the birds. The only areas where goosanders clearly consumed large numbers of fish of economic interest, were in places where the fish community contained relatively few species, and such fish were predominant. These were mainly salmonid dominated northern fast-water rivers, or salmonid stocked fisheries which are artificially impoverished. There is no published estimate of the diet of goosanders in England and Wales, where fish communities are more diverse than in Scotland, and where there are stocked coarse fisheries.

Table 5. The principal fish prey species (>10%) in order of importance, from samples of stomachs of goosanders (common mergansers) of varying provenance.

Region	Habitat	Season	Principal prey	Authority
NORTH AMERICA				
Alaska	River	Summer(dklg)	cottids	Fritsch & Buss 1958
Brit.Col'bia	Lake	Autumn	kokanee	Munro & Clemens
1937	Lake	Summer	sculpin, sucker, chub, shiner	"
	River	Spring	pink salmon, sculpin	"
	River	Summer	sculpin, stickleback.	"
	River	Autumn	salmon eggs	"
	Coast	Spring	sculpin	"
	Coast	Autumn	sculpin, perch.	"
N.Brunswick	River	Autumn	salmon, common shiner.	White 1957
	River	Summer	salmon, blacknose dace, lake chub,c.shiner.	"
	River	Summer(dklg)	shiner, salmon.	"
	River	Summer	white sucker, salmon, blacknose dace.	"
	River	Autumn	shiner, fallfish, sucker.	"
	River	Winter	white sucker, eel, shiner.	"
	Lake	Winter	smelt, white sucker, eel	"
	Lake	Summer	shiner, white sucker, killifish	"
(Pollett)*	River	Year round	salmon (hatchery), white sucker, lake chub.	"
(Pollett)*	River	Summer(dklg)	shiner	"
Nova Scotia	River	Summer	white sucker, shiner, salmon, killifish.	"
	River	Summer	salmon, white sucker, eel, stickleback.	"
	River	Autumn	alewife, white sucker, shiner.	"
	River	Winter	eel.	Coldwell 1939
(Margaree)*	River	Year round	salmon, brook trout.	White 1957
Michigan	River	Winter	brown trout, rainbow trout.	Leonard &Shetter
1936				
"	Lake	Winter	yellow perch, emerald shiner.	Salyer & Lagler
1940				
"	River	Winter	brown trout, rainbow trout, brook trout.	"
"	River	Winter	rock bass, smallmouth bass, carp.	"
"	River	Winter	brook trout (hatchery stocked).	"
Ontario	River	Spring	percids (yellow perch & darters)	Englert & Seghers
1983				
Washington	Lake	Winter	rainbow trout (hatchery stocked).	Meigs & Reick 1967
Oklahoma	Lake	Winter	gizzard shad.	Heard & Curd 1959
	Lake	Winter	gizzard shad.	Miller & Barclay 1973

*Rivers involved in the goosander removal ‘experiments’ in Eastern Canada (see text).

Table 5 (continued).

N.C. USA	River	Autumn	gizzard shad.	Timken & Anderson 1969
"	River	Winter	gizzard shad.	"
"	River	Spring	white bass.	"
"	Lake	Autumn	freshwater drum.	"
Nevada	River	Winter	carp.	Alcorn 1953
"	Lakes	Winter	carp, yellow perch, Sacramento perch.	"
New Mexico	R'voir	Winter	shad, carp, white crappie.	Huntingdon & Roberts 1959
"	River	Winter	shad, carp.	"
SOVIET UNION (as at that time)				
Pechora	River	Summer	minnow, grayling, salmon.	cited by Dementiev &
Mologa	River	Spring	bullhead, perch.	Gladkov 1952.
Rybinsk	R'voir	Spring	burbot, roach.	"
"	R'voir	Autumn	roach, ruffe, perch, smelt.	"
Volga	R.delta	Autumn	roach, carp, pike.	"
Caspian	Sea	Winter	gobies, sandsmelt.	"
EUROPE				
Sweden	Lake	Winter	cyprinids, mainly roach.	Nilsson 1974.
"	Coast	Winter	eel, long-spined sea scorpion.	"
"	River	Spring	river lamprey.	Sjoberg 1989.
"	River	Summer	salmon / trout, bullhead.	Lindroth 1955.
Norway	River	Spring	trout.	Lid & Schandy 1984.
"	River	Summer(juvs)	minnow.	"
"	Estuary	Summer	butterfish, gadoids, char, cottids.	Kalas *et al* 1993.
Denmark	Coast	Winter	eel, stickleback, eelpout, black goby.	Madsen 1957.
"	Lakes	Winter	dace, rudd, bleak, roach, 10-sp.stickleback.	"
Finland	Coast	Spring	3 sp.stickleback, eelpout, roach.	Bagge *et al* 1973.
Scotland, Great Britain				
(various)	River	?	salmon, perch, brown trout, eel.	Mills 1962
Dee	River	Spring	salmon, trout, eel.	Feltham, Marquiss &
"	River	Summer	salmon, trout.	Carss (unpublished)
North Esk	River	Spring	trout, salmon, eel, frog.	"
Tweed	River	Spring	eel, lamprey, trout, salmon.	Marquiss & Carss(in prep)
"	River	Summer	eel.	"
"	River	Summer(dklg)	minnow, stoneloach, large insects.	"
"	River	Winter	eel.	"
Loch Leven	Lake	Winter	Perch.	Allison *et al* 1974

Table 6. The sizes (cm) of fish consumed by goosanders (common mergansers). References as in Table 5.

Habitat	**Fish species**	**Range of recorded sizes** (smallest - largest)	**Most common sizes** (means, medians or modes; various studies)
N AMERICA			
Lakes	gizzard shad	5-33	5, 11, 13.
	freshwater drum	9-21	14
	white crappie	7-28	10, 23.
	carp	3-32	23
	Sacramento perch	4-11	
	yellow perch		10
	suckers	10-25	18
	sculpin		11
	largemouth bass	6-25	
	rainbow trout		11
Rivers	eel	7-46	10, 17.
	Atlantic salmon	3-14	6, 8, 9.
	Pacific salmon	4-11	5
	brook trout	8-15	
	shiners	3-10	6, 6.
	white sucker	4-25	4, 11.
	alewife		6
	blacknose dace	6-7	6
PALEARCTIC			
Lakes	roach	10-20	9, 14.
	perch	4-20	5
	brown trout	13-51	25
	dace	3-6	
	bleak	5-9	
	10-sp stickleback	3-5	
Rivers	eel	12-37	19
	salmon	3-13	6, 7, 7, 7, 8, 8, 9, 10.
	brown trout	3-33	10, 13.
	sculpin	4-12	6
	3-sp stickleback	2-7	5
	lamprey sp	9-33	11, 26.

2.2.3. Foraging behaviour

Goosanders locate fish in two ways, either by surface swimming with their bill and eyes submerged scanning for fish, or by diving (Lindroth and Bergstom 1959, Sjoberg 1988). The first method is used on rivers in shallow or clear water, and is interspersed with chases presumably as suitable prey is located. Chases can be under or above the water surface, the duck propelling itself with its legs and feet, and fish may be captured and swallowed, lost, or run to ground. If a fish is run to ground it can sometimes be caught if, by probing with it's bill, the goosander can dislodge it from its refuge and continue the chase. When no fish are visible, goosanders often probe with their bills under stones and can flip over smaller stones (Sjoberg 1988). They also probe in soft substrates and in vegetation, particularly in the fringes of lochs and along banksides, where they take eels and frogs (pers obs).

Presumably the same sorts of behaviour are used when the bird is searching for fish underwater, either locating and pursuing fish in shoals, or probing for fish hidden in the substrate. In a similar fashion to cormorants, social flock-fishing by goosanders occurs in circumstances where they are feeding on large shoals of midwater schooling fish, such as gizzard shad in warm water reservoirs (USA), or on clupeid fish in shallow water firths (Beauly in Scotland). Such social fishing is probably most efficient when the birds feed in very large (>1200) flocks because the volume of fish in the stomachs of birds shot from these flocks was greater than for those from small (<20) flocks (Huntingdon & Roberts 1959). In the same way as has been proposed for cormorants, the sequential diving of large numbers of birds in pursuit of the fish shoal could exhaust the smallest of fish. Social fishing could also be involved in the pattern of food searching by broods of goosanders which sometimes swim line abreast. This configuration means individual birds are not searching over areas that have just been swum over, and also that disturbed fish might swim into the path of an adjacent bird. However the success rate of birds feeding in this fashion is no better than that of birds foraging alone (Wood & Hand 1985).

Considering these foraging behaviours it seems that fish are most vulnerable to predation by goosanders, if they are easily seen, if they cannot outstrip the duck by swimming fast, or if they cannot find a secure refuge. Consequently, it might be expected that cryptically marked fish, that are well fed, vigilant and 'freeze' at the approach of a predator, would be at an advantage. Conversely, fish that are hungry because they need to grow fast, have a poor food supply, or have gut parasites will be more active, less vigilant, and thus disadvantaged (review in Milinski 1986). Also it would be expected that slow swimming species would be more vulnerable than others, and amongst fast swimming fish, the smallest individuals will be the most vulnerable because they have the lowest burst speed and the least stamina. Moreover in areas used by goosanders, habitats with ample cover would theoretically be best for those fish species that tend to go to ground, and there should be selective advantage in individual fish defending a foraging site with a good refuge close by.

There is some evidence to support these ideas. Where a variety of fishes are available, fast swimming fish do not dominate the diet (Table 5). Predation experiments using captive sawbills have shown that cryptically marked fish were less likely to be consumed than those that had not 'acclimatised' to the colour of the background (Donnelly & Whoriskey 1991), and fish escaping by seeking refuge were less likely to be caught than those that tried to swim away (Sjoberg 1988). In experiments using hatchery fish, Wood & Hand (1985) showed that wild goosanders were less successful in catching fish in enclosures with cover from undercut banks, and that naive fish were more prone to predation than those that had previous experience of goosanders. Finally, on two rivers in northeast Scotland, in April, there was strong size selection by goosander (and red-breasted merganser) for the smallest of salmon smolts (Feltham 1990 & in prep) and on a river in north Norway, in June, for the smallest of Arctic char smolts (Kalas *et al* 1993).

2.2.4. The amount of fish consumed by goosanders

As with studies of cormorants, the majority of studies on the food demands of sawbill ducks (Table 7) have involved measuring the food intake of captives, which probably underestimates the intake of free living birds that are more active. The 'full' stomachs method, as already explained, will be an overestimate and Nilsson and Nilsson's empirical equation is itself based upon estimates of undefined accuracy. Intake of goosanders could thus be anywhere between one fifth and one third of body weight (between 240 and 520 g) per bird per day. The larger percent values for ducklings in Table 7 are expected because, relative to body weight, the intake of ducklings should be greater than that of fully grown birds with the additional energy demands of growth and their greater time spent active (Marquiss & Duncan in press b).

Table 7. Estimates of the daily food intake of goosander / common merganser (G) and red-breasted merganser (RBM) from studies using various methods.

Study	Species	Method	Intake (% body weight)
Salyer & Lagler 1940	G	'full' stomachs of shot birds	ca33-50
White 1957	G	captives	22-39
Latta & Sharkey 1966	G	captives	18-27
Miller & Barclay 1973	G	captives	20
Nilsson & Nilsson 1976	G	empirical equation for fish-eating birds	18
White 1957	G	captive ducklings	30
Wood 1987	G	visual obs wild ducklings	80-40 (10-40 days age)*
Atkinson & Hewitt	RBM	captives	29
Carter & Evans 1986	RBM	theoretical energy demand (3x BMR)	23

*Intake as a percent of body mass decreasing with age, ie with increasing mass.

2.2.5. Population trends in Europe and Great Britain

Goosanders breed at relatively low densities so the monitoring of breeding populations is difficult and most statements regarding widespread changes in its breeding abundance are necessarily vague. For example, goosanders have apparently declined in southern Sweden in association with the acidification of lakes, but the decline has not been quantified (Hansen 1980). Most well documented trends in breeding populations have been restricted to small study areas (eg in Finland, Niittyla 1980) or have recorded changes in the breeding range. Thus the colonisation and increase of goosander populations in the southern part of the range are quite detailed. The species was a rare breeding bird on Lake Geneva in the early decades of this century but increased dramatically to about 700 pairs in 1984 (Geroudet 1985). The colonisation of Great Britain has been detailed (Berry 1939, Mills 1962, Parslow 1973, Sharrock 1976,Meek & Little 1977b & 1980, Lovegrove 1978, Tyler 1986, Griffin 1990, Gibbons, Reid & Chapman 1993, Carter 1993) alongside some of the local increases that have characterised the colonisation process. In contrast, apart from some recent counts on three rivers in Scotland (Murray 1992, Marquiss unpub.), long-term changes in abundance within the established range have not been documented.

Goosanders have only bred in Great Britain in the last 100 years or so. First proved breeding occurred in 1871 in Perthshire, and they were widely distributed breeding birds in Scotland by the turn of the Century. Thirty years later southern Scotland was colonised, followed by northern England in the 1950s. Breeding began in County Durham in 1965, Yorkshire in 1970 and Lancashire in 1973. First confirmed breeding in Wales was in 1972; there were 10 pairs by 1977 and 81 pairs by 1985 (Tyler, Stratford & Lucas 1988). A survey in Wales in 1990 found the bird had expanded its breeding range to other rivers though the overall numbers remained the same (Griffin 1990). Goosanders bred on the river Dart in Devon in 1980 and have increased slightly since (Sitters 1988).

Breeding distribution maps have been produced from fieldwork done by BTO members in 1968-72 (Sharrock 1976) and in 1988-91 (Gibbons *et al* 1993). The first map shows breeding goosanders were widespread in northern Britain, but concentrated in southern Scotland and northern England. The second differs because of the range expansion that has taken place since then, with more breeding further south in the Pennines, Wales and southwest England. The second survey incorporated indices of abundance to provide a quantitative baseline estimate. Additionally, the BTO organised a national sawbill survey on rivers in spring and summer 1987, to estimate the density of birds in various parts of the breeding range and the total number in Britain. Carter (in Gibbons *et al* 1993) estimated average breeding densities of 0.18, 0.21 and 0.08 pairs per kilometre of river in Scotland, England and Wales respectively.

The total breeding population of western Europe is unknown, but could be in the region of 30,000 to 40,000 pairs (guessed from wintering numbers cited in Ruger *et al* 1986). The population in Britain was estimated to be between 1000 and 2000 pairs in 1968-72 (Sharrock 1976), between 915 and 1246 pairs in 1975 (Meek & Little 1977b) and about 2700 pairs in 1987 (Carter, in Gibbons *et al* 1993). The spring numbers of goosanders on the River Tweed, estimated at 444-490 from counts in 1984, 1986, 1987 and 1991 (Murray 1992) have shown no significant annual trend, whereas the breeding population of 62 pairs in 1988, on the river Dee in Aberdeenshire, halved over the subsequent five years to 1992 (Marquiss unpub.).

The winter population of western Europe was most recently estimated at 100,000 - 150,000 birds (Ruger *et al* 1986). These authors point out that the figures varied considerably, associated with uneven coverage between years. There were a few sites with large concentrations, but most birds were well dispersed in small groups at a large number of sites making overall estimates difficult, and time trends almost impossible to detect. Coordinated aerial counts of goosanders in the Baltic would produce a more accurate estimate of the total wintering population.

Similar problems surround estimates of the numbers wintering in Britain (as discussed in Starling *et al* 1992). Nevertheless their analysis of National Waterfowl Counts showed a significant increase in the wintering population of Britain from the 1960s onwards, mainly over the decade 1969/70 to 1979/80, numbers stabilising thereafter, in parallel with the range expansion of breeding birds, which slowed considerably in the 1980s. The increase occurred as a result of more birds on more sites covering the full spectrum of habitats, though particularly gravel pits. The most important wintering site was the Beauly Firth (inner Moray Firth) where there were at one time well over a thousand birds all winter. Since the mid 1980s however, the numbers have declined to one or two hundred which leave before midwinter (Marquiss unpub.). This change was thought to be associated with a decline in clupeid shoals (and in other fish-eating birds) and there is no evidence of another concentration of goosanders arising elsewhere in Britain. It seems that the birds have died out or have dispersed to other locations, perhaps accounting for minor increases in counts at many other sites. Some regular counts on three Scottish rivers in the 1980's have suggested little change in numbers over a series of winters (Murray 1992, Marquiss unpub.).

The total wintering population was estimated in the BTO winter survey at about 8,000 in 1981-84 (Chandler in Lack 1986), of which about 5,000 were in northern England and Scotland. From National Waterfowl Count data, Owen *et al* (1986) estimated about 5,000 birds and most recently Starling *et al* (1992) estimated 5,500. The discrepancy between estimates could be due to some birds being counted twice in the BTO winter atlas survey. Alternatively, many birds wintering on rivers might remain unaccounted in the National Waterfowl Counts. Bearing in mind such problems, the numbers are not inconsistent with the idea that goosanders are largely resident in Britain with relatively few continental immigrants in winter (Owen *et al* 1986). This in turn implies that the overall increase in the British population has probably now slowed, if not halted, and that henceforth it might merely fluctuate according to changes in breeding production and overwinter food availability.

2.3. Red-breasted merganser

2.3.1. Distribution, habitat, breeding and movements

The red-breasted merganser is a predominantly marine species living in shallow coastal waters. Most of the British population breeds in sheltered sealochs and estuaries, and a small but perhaps increasing proportion breeds in the slower-flowing, wider, lower reaches of rivers (Marquiss & Duncan 1993) and on freshwater lakes, which is the commoner breeding habitat elsewhere in the range (Cramp & Simmons 1977). Almost all red-breasted mergansers spend the winter on the coast, entering freshwaters in late April and May, producing eggs in May and June and young in July and August (Marquiss & Duncan 1993).

Egg-laying is probably slightly later at higher latitudes (comparing dates in Dementiev & Gladkov 1952, Rehfeldt 1986, Bengtson 1972, Hilden 1964 and Sjoberg 1989). Seven to 12 eggs (sometimes many more in 'multiple clutches', Young & Titman 1988) are laid in a scrape on the ground amongst vegetation, and the young leave the nest within a day or so of hatch to feed themselves, though led and protected by the female. One female can guide many ducklings which sometimes congregate into a single large group (creche), particularly where several females nest close by one another (Martin 1988). The habit of creching is far more common in red-breasted mergansers, than in goosander broods (Bergman 1956) and the biggest of creches have been found on shallow lakes and estuaries (Hilden 1964, Gardarsson 1979, Macdonald 1987c and Marquiss & Duncan 1993). Average production in individual years has varied from 0.9-2.5 ducklings per spring female, on the rich shallow lake Myvatn, Iceland (Bengtson 1972) and 0.7-2.0 in the shallow brackish Gulf of Bothnia (Hilden 1964), to 0.7-1.8 on a river in Northeast Scotland (Marquiss & Duncan 1993). In this latter study, low duckling production was associated with high river flows at the time of hatch and in the subsequent 10 days.

Adult red-breasted mergansers moult their wing feathers in August and September, at this time congregating in open areas of shallow water. In Britain, all the currently recorded moulting sites are on the coast around Scotland, Northumberland and North Wales (Owen *et al* 1986, Marquiss & Duncan 1993, Dickson 1987, Andrews 1987, Starling *et al* 1992, R.Broad, L.Hatton, D.C.Jardine, B.Little and M.Marquiss unpublished). After moult, the birds become more widely distributed around the coast, with fewer large aggregations (Owen *et al* 1986, Aspinall & Dennis 1988, Starling *et al* 1992).

2.3.2. Diet

As with studies of goosander diet, much of the information on red-breasted merganser diet comes from samples of shot birds from areas where it was thought the birds could conflict with fishery interests. Despite this emphasis, most studies (Table 8) have shown they eat small fish (2-10cm, Cramp & Simmons 1977), mainly sticklebacks, shiners, minnows and gobies, but also large insects and shrimp. On some rivers in Scotland, they ate juvenile salmon (Feltham 1990) but only in any quantity during April. Moreover, the fish consumed were very small (3-13 cm) mainly parr (mean 7 cm) but including some small smolts (mean 11.5 cm) from the beginning of the smolt migration.

Some studies have not looked at diet directly, but deduced it from a combination of visual observations of foraging birds and an association with certain habitats which supported mainly one or two species of small fish. From this it is inferred that the diet consisted of sandeels, young clupeids, shrimp, flatfish and sticklebacks on the coasts of Scotland in autumn and winter (Berry 1936, Aspinall & Dennis 1988, Marquiss pers obs); predominantly insects and sticklebacks in spring and summer in the north of the breeding range (Hilden 1964, Bengtson 1971, Rad 1980); but including some other species such as eels (Berry 1936), minnow (Rehfeldt 1986) or perch fry (Atkinson & Hewitt 1978) in the south.

Table 8. The principal fish species in order of importance, in samples of stomachs of red-breasted mergansers of varying provenance.

Region	**Habitat**	**Season**	**Principal prey**	**Authority**
North America				
Nova Scotia	River	summer	salmon parr, stickleback.	White 1957
N.Brunswick	River	summer	shiner, white sucker, stickleback.	"
"	Lake	summer	stickleback, shiner.	"
"	Estuary	summer	stickleback	"
Russia				cited in Dementiev & Gladkov 1952
Pechora	Estuary	spring	minnow, sculpin, insects.	
Rybinsk	Res'voir	autumn	caddis flies.	
Caspian	Sea	winter	carp, bleak.	
Europe				
Sweden	River	spring	stickleback.	Sjoberg 1985
Sweden	River	summer	bullhead, salmon/trout.	Lindroth 1955
Finland	Coast	spring	stickleback.	Bagge et al 1973
Denmark	Coast	winter	stickleback, goby, shrimp,eelpout.	Madsen 1957
Netherlands	Brackish	winter	goby, shrimp.	Doornbos 1984
Scotland	River	spring	salmon, brook lamprey, minnow, eel.	Mills 1962b
Scotland	River	spring	salmon, trout.	Feltham 1990
Scotland	River	summer(juvs)	trout, minnow.	Carss & Marquiss,
Scotland	Estuary	summer(juvs)	stickleback, gadoids.	Feltham, unpubl.

2.3.3. Foraging behaviour

Red-breasted mergansers feed in similar ways to goosanders except for a tendency to use their wings underwater (Dementiev & Gladkov 1952) and for more diving and less surface scanning than goosanders when searching for prey (Sjoberg 1988). Both these features could be associated with red-breasted mergansers' greater use of deeper, slower moving waters, that often have soft or sandy substrates and can be more turbid (Cramp & Simmons 1977). Similar to goosanders, they sometimes congregate to forage socially (eg Hending, King & Prytherch 1963, Emlen & Harrison 1970) and they can show diurnal patterns of foraging correlated with the activity rhythms of their major prey (Sjoberg 1989).

2.3.4. The amount of fish eaten by red-breasted merganser

Only two published studies were found that have estimated the food intake of red-breasted mergansers, one from captives and another on a theoretical energetic demand basis (Table 7). The values, 29% and 23% of body weight per day are similar to those for goosanders, and represent an intake of between 210 and 320 g per bird per day.

2.3.5. Population trends in Europe and Great Britain.

Red-breasted mergansers can be relatively easy to count on the sea close inshore, and on estuaries and lakes, but are more difficult in the open sea (without aerial surveys) or on upstream sections of rivers (Marquiss & Duncan 1993) mainly because it takes time to count long sections and the birds move over several kilometres of river. The numbers at specific count sites can fluctuate erratically from year to year so it is thought that birds readily shift foraging and moulting areas, perhaps associated with shifting food availability. Moreover, there are relatively few ringed bird recoveries so their movements are poorly documented (Cramp & Simmons 1977, Owen *et al* 1986, Ruger *et al* 1986). It is therefore not surprising that the wintering population of northwest Europe is only roughly estimated at about 40,000 and the total breeding numbers are unknown.

As with goosander, the best documented population change is in Britain where numbers have increased alongside an expansion in breeding range. Red-breasted mergansers have long bred in Scotland but the population increased dramatically from about 1885 to 1920, spreading into northern England in 1950 and north Wales in 1953 (Parslow 1973, Cramp & Simmons 1977, Owen *et al* 1986). Although the breeding population of Britain continued to be concentrated in western Scotland, by the time of the 1968-72 Breeding Bird Atlas (Sharrock 1976) there were well established populations in the Lake District, Anglesey and North Wales. The 1988-91 breeding atlas (Gibbons *et al* 1993) documents further colonisation in the Peak District and southwards in Wales, and gives the best current estimate of population distribution.

There has been no direct attempt to census the whole breeding population of Britain and Ireland. The 1987 national sawbill survey was devised to estimate goosander numbers and so it ignored most of the red-breasted merganser breeding habitat on the coast, and conducted spring river counts in April. Many red-breasted mergansers in the north do not arrive on their breeding grounds until May, so April counts in Scotland can underestimate the breeding population by between 3% and 52% depending on annual variation in the timing of arrival (Marquiss & Duncan 1993). Duckling counts in July are also at the wrong time, because by then most male red-breasted mergansers have left the river to moult, and many females are still incubating eggs. The British breeding population cannot be estimated from counts of moulting drakes, or from winter counts, until more is known about the provenance of these birds. The first breeding bird atlas of 1968-72 estimated the population at 2,000 to 3,000 pairs in Britain and Ireland (Sharrock 1976) by multiplying the area occupied by birds by a guess at breeding density (3 to 5 pairs per 100 km^2). The abundance indices accompanying the most recent breeding distribution map (Gibbons *et al* 1993) give a current (1988-91) estimate of 4,300 in Britain and 1,400 in Ireland, suggesting minimum populations of 2,150 and 700 pairs respectively.

The wintering numbers of red-breasted mergansers have been monitored using National Waterfowl Counts and trends have broadly followed trends in the index for goosander, with an increase from 1962/3 to 1979/80, but not since (Starling *et al* 1992). This again parallels expansion and increase in the breeding population and could perhaps be circumstantial evidence of residency. Owen *et al* (1986) estimated the winter population at 6,000 to 10,000 birds.

3.THE IMPACT OF FISH EATING BIRDS ON FISHERIES

3.1. Fish population dynamics

With respect to the impact of predation on fish populations, a major concern is whether the size and structure of a fish population is influenced most by changes in lower, or higher, trophic levels. In other words, are fish populations regulated 'bottom-up' by their resources, or 'top-down' by their predators? A recent comprehensive review of temperate stream and lake fish community studies (Karr, Dionne & Schlosser 1992) concluded that generalisation was difficult - there was good experimental evidence for both bottom-up and top-down influences as well as for the direct effects of abiotic factors. Most importantly, the review stressed the complexity of fish community relationships. Experimental studies showed some simple trophic relationships, whereas detailed studies in natural environments suggested far more complicated local dynamics. An important feature of such dynamics involved the movements of fish as they shifted between habitats, trading off predation risk against food availability. This topic has been reviewed in detail in Milinski (1986), Mittelbach (1986) and Dill (1987).

In the review by Karr *et al* (1992) the most detailed and comprehensive of community studies (by Power and Schlosser in streams, and Mills, Persson, DeVries and others in lakes) did not involve avian piscivores, only fish predators such as bass *Micropterus*, perch, zander and pike. This was probably because of the paucity of detailed experimental community studies involving bird piscivores - fish are easier to use than birds in controlled manipulative experiments. Nevertheless, within the context of avian predation as a potential problem, the implications of the review by Karr *et al* (1992) are obvious - at present, neither an effect of bird predation nor the lack of one, can be assumed.

In various circumstances, predation by birds might affect (i) the overall abundance of fish, (ii) the relative abundance of various size classes or age classes of fish, or (iii) the habitats used by fish, and thus their potential growth rate and population density. Conversely, given the complexity of fish community relationships, it is probably rare for fish populations to be moulded by avian predation alone. This means that any postulated impact of fish-eating birds on fish populations needs to be demonstrated unequivocally before it can be accepted universally.

This is not very easy to do. Most freshwaters in Britain are not stable but in flux; changing in association with a fluctuating climate, natural ecological succession or (most often) anthropogenic influences, such as nutrient and sediment input, water acidification, weed control, fish stocking and fish introductions. Thus, reduced fish catches cannot be attributed with certainty to increased bird predation *per se* when they are so often accompanied by other environmental changes. Properly controlled experiments are the only way to demonstrate "cause and effect".

3.2. Experimentation

The process of demonstrating "cause and effect" in assessing avian predation on fish populations involves three stages. (i) the hypothesis (of a specific impact) is raised, (ii) the putative causal factor (bird predation) is artificially changed, and (iii) the measured outcome (eg fish population size) is compared against the measured outcome from a "control" - an identical experimental set up but with no manipulation of the putative causal factor. In this way, the effects of other factors can be ruled out.

Hypotheses can be generated in a variety of ways - for example, by theoretical argument (logic), by using empirical information from specific instances (anecdotes) or by quantitative prediction (modelling). For example, in the case of bird predation a logical argument might be that avian piscivores eat salmon so in the presence of such birds there could well be fewer to harvest. Anecdotal information might include observations of the aggregation of fish-eating birds on rivers during the salmon smolt migration, or an increase in the number of birds seen coincident with a decline in salmon catches. Quantitative predictions might be derived from calculations of the number of fish thought to be consumed by birds, together with varying estimates of mortality for those surviving bird predation. Modelling these relationships allows a series of predictions for the outcome from the partial removal of bird predation. Provided the information is accurate and the model in some way resembles reality, more quantitative information means better prediction and in theory, a better designed experiment.

The experimental manipulation of bird predation can be simple on fish cages or in small ponds because birds can be totally excluded using netting. On larger water bodies and on river systems removing bird predation usually involves removing birds, which can present logistic problems and in some circumstances it may prove totally impractical.

Similarly, the measurement of the outcome can be relatively easy for small enclosed systems such as on a fish farm or at a small put-and-take fishery, where harvest can be almost complete. In contrast, where an experiment involves river systems, large lakes or even the sea, and there are intervention fisheries, some outcomes could be very difficult to measure without substantial resources. Most importantly, with larger, open systems it is difficult to match the experimental site to a suitable control site. The best of field experiments should therefore include repetition, reversing the procedures between experimental and control sites.

Finally, experiments should attempt to tackle a specific question directly, rather than piecemeal. Scientists might find interest in estimating the effect of avian predation on fish density or the age structure of fish populations. Experiments quantifying such will be important in assessing the likelihood of birds affecting fisheries, but less useful to a fisheries manager than an experiment devised specifically to find out whether shooting fish-eating birds increases fish harvest in a cost effective manner.

Field experiments are the only way to demonstrate the impact of fish-eating birds on fish populations, but they are expensive and difficult to carry out. Accordingly, assessments of impact have had to rely on a mixture of anecdotal and circumstantial evidence, together with the results of a few attempts at field experiments. In general, it is easy to argue both for and against the perceived effects of fish-eating birds, but by using information on diet and bird abundance, substantial impact can often be ruled out, leaving only a few specific situations where bird impact might be sufficient to lead to fishery losses, and where experimentation need be applied to resolve it.

3.3. The impacts of cormorants on fish populations

Many fishermen in the countries of at least three continents believe that cormorants influence fish populations and thus recreational angling or fishery harvest. Cormorants are large, are seen to catch large fish, and sometimes congregate in numbers (section 2.1). It logically follows that at least in some places they could be consuming large quantities of fish potentially to the detriment of fishermens catches, assuming that the fish taken are those that might be otherwise caught by man. Moreover, the cormorant population has been increasing in North America and Europe for the last 25 years so any decline in fish catch during that period can be shown to have been accompanied by an increase in cormorants. Such superficial evidence is sufficient to raise the hypothesis of an impact, but closer scrutiny is required. The quality of evidence for impact varies according to the nature of the fish population and habitat so the evidence is reviewed separately for fish farms, stocked fisheries, natural fish populations in large lakes and on rivers.

3.3.1. Cormorants at fish farms

On fish farms the fish stock is usually known and it is possible to quantify losses. At cage farms, the stock is held in nets suspended from a floating collar which is itself netted over. Cormorants are attracted to cage farms, feeding on the the large concentrations of wild and escaped fish in the waters immediately adjacent to cages (Carss 1990b) but also attacking stock through the net meshes (Ranson & Beveridge 1983, Carss 1993). Stock fish damaged by attacks cannot be removed by cormorants but nevertheless suffer fatal injury. The amount of stock lost to cormorant damage, estimated using the presence of characteristic wounds (Carss 1990a), was tiny and averaged only 0.4% of overall mortality. A comparison between protected and unprotected cages showed losses could not be totally eliminated but were reduced substantially by using properly positioned, underwater antipredator netting (Carss 1993).

There is little evidence that cormorants cause problems at tank or pond farms in Britain (Carss & Marquiss 1992), probably because they are too small (Moerbeek *et al* 1987). In other parts of the world, fish farm stock is often kept in much larger ponds where cormorants are seen to consume many fish and losses can be substantial (Steiner 1988, Broadway 1989, Muselet 1991, Osieck 1991, Zimmermann & Rutschke 1991, Marion in press, Mellin & Mirowska-Ibron in press, Shchegolev, Rusev & Korzyukov in press). Losses have been variously estimated at 50% (Barlow & Bock 1984), 43% (Im & Hafner 1984) and even up to 90% in one study (Moerbeek *et al* 1987). Because fish are removed, the losses to bird predation are not often measured directly and can be overestimated if other sources of mortality are not quantified. Ideally, losses would be best estimated by comparing the yield of predated ponds against those where cormorants are excluded but this seems difficult to achieve, so the best current estimate was derived from a comparison with small ponds that were not used by cormorants (Moerbeek *et al* 1987). Despite the lack of rigorous comparisons, it is undoubtedly true that cormorants can remove very large amounts of stock fish that would otherwise be harvested. Moerbeek *et al* (1987) also noted that flocks of cormorants landing on ponds, alarmed fish to such an extent that it could have reduced their feeding. Cage fish farmers in Scotland have also claimed that predator attacks, or even the mere presence of a predator nearby, can induce stress in fish leading to a disruption in feeding, poor growth and an increased susceptibility to disease (Carss & Marquiss 1992a) However, this has not been investigated and the evidence remains anecdotal. Most studies at fish farms have concentrated on devising mechanisms to exclude cormorants, or at least to reduce their numbers, and on varying stocking practice to reduce losses.

Excluding cormorants from anywhere other than small ponds is difficult. Moerbeek *et al* (1987) tried various patterns and spacing of ropes above the water surface and found optimal configurations but nothing that kept birds out altogether. However, the use of such ropes prevented the previous mass incursion of cormorant flocks that alarmed fish and removed large quantities of fish immediately following stocking. Moerbeek *et al* also recommended cage enclosures within ponds to protect small fish from cormorants until they grow too big to be eaten.

Scaring is only partially successful, the birds rapidly getting used to most devices which involve loud noise, bright objects and even broadcasts of cormorant distress calls (Moerbeek et al 1987, Im & Hafner 1984, Barlow & Bock 1984, reviewed in Draulans 1987). The only persistent deterrent was human presence, and presumably this too has to be frequently endorsed by chasing the boldest of individuals away. Following on from this, practical recommendations included placing the most vulnerable of stock in ponds closest to areas where most people worked, encouraging public use of the farm (eg for angling) and stocking the site at a time of year when cormorant numbers are declining, or as late as possible in the spring to reduce the time over which there might be recruitment of cormorants feeding at the farm (Osieck 1991).

Most exclosures and deterrents work best when the birds have an alternative foraging site, so the converse is that given no better alternative, the birds will be even more persistent. The concentration of fish at farms is so attractive that even the shooting of birds at farms will be ineffective in removing the problem until the majority of the cormorant population has been killed, a mammoth and impractical task (Zimmermann & Rutschke 1991).With this in mind, it seems the best defence is to provide exclosures and deterrents together with an alternative, easier food source - perhaps a stock of lower value fish on an adjacent pond. Barlow & Bock (1984) recommended lowering the density of fish and stocking prey which were easier for cormorants to catch.

3.3.2. Cormorants on stocked stillwaters

Stocked stillwater sites can be small lakes and ponds which support exclusively large fish introduced for recreational angling (put-and-take fisheries), or stillwaters of various sizes where the existing fish population has been enhanced by introducing hatchery-produced fish of various sizes. In Britain, such stillwaters have increased dramatically over the last 20 years as existing waters have been stocked to satisfy the demand for recreational angling, and new stillwaters (reservoirs, gravel pits and fishery ponds) have been created and then stocked with fish. Cormorants can aggregate at such sites in winter, increasing from October to February, (Feare 1987, Starling et al 1992, Carss & Marquiss 1992b). The winter peak varies between sites and the number of birds foraging can be considerably less than those roosting (Feare 1987).

There is some evidence that the cormorants using these sites are feeding on stocked fish. Cormorants shot at one fishery in Scotland contained exclusively rainbow trout which do not breed at the site and so must have been introduced stock. Moreover, some of these fish were of 'takeable' size so it could be argued that cormorants were competing directly with anglers for these fish (Carss & Marquiss unpub.). However, the issue of competition is only important if a large proportion of stocked fish are ultimately harvested. If there are other sources of mortality or if only a small proportion of fish are harvested, the fish freed from cormorant predation will only contribute a small fraction to anglers catches. The fishery manager needs to know whether reducing cormorant predation (by whatever practical means available) results in significantly greater catches for anglers.

There is circumstantial evidence that the process of stocking fish affects cormorants. Prior to stocking, at Loch Leven in Scotland, the diet of cormorants was mainly perch with some trout; after stocking with thousands of hatchery-reared trout, the diet changed significantly to trout alone (Carss & Marquiss 1992b). About half of these fish were over 23 cm long and could have been kept after capture by anglers. Following on from the stocking programme, the average wintering cormorant population increased from about 70 to over 200, mainly due to the presence of more birds in late winter and spring, when over 500 birds were often counted. Angling catches also varied, initially increasing following stocking but then declining dramatically. The circumstantial evidence from the increase in cormorants and their diet of trout, suggested that reduced catches could have been caused by losses of trout to cormorants.

However, a stock assessment using gill nets showed that the trout population was exceptionally high, so angling catches were not a good measure of fish abundance. Further complicating issues at Loch Leven were the artificial removal of pike, a decline in the perch population, a high nutrient input, large changes in aquatic macrophyte cover and problems with algal blooms in some years. In the absence of controlled experiment, with so many simultaneous changes occurring in the loch and no annual estimate of the trout population, it was difficult to identify what reduced angling catches, let alone whether cormorants were involved. Throughout this time cormorants were frequently shot at Loch Leven, but this killing did not reduce cormorant numbers nor did it improve angling catches.

Presumably shooting did not reduce cormorant numbers because they can commute long distances and are attracted to places with an abundance of medium-sized fish. Even if it was properly shown that cormorant predation affected the fish population, and reduced catches, it is difficult to imagine what could be done to prevent it. On large water bodies exclosure is impossible and deterrents are ineffective so the problem could only be resolved by reducing the attraction - that is by making the stocked fish less easily caught than the nearest alternative. One way of doing this is to reduce the stocking density of trout and increase alternative forage by stocking buffer populations of low value fish, such as perch. Another approach is to stock at times of year when cormorants are leaving the area. This may not be an option at some sites in the future if inland breeding cormorants continue to increase, as predicted.

3.3.3. Cormorants on large lakes

Large lakes often support commercial freshwater trawl or seine fisheries as well as recreational angling. Cormorants can number hundreds or thousands at some of these sites such as at Lake Malawi (Linn & Campbell 1992), Ijsselmeer (Osieck 1991) or Lake Geneva (Suter 1991). Under these circumstances, it is impractical to try to remove cormorant predation and the evidence of impact on fish populations is usually anecdotal or at best circumstantial. Often, the main evidence put forward is of a decline in fish catches associated with the increase in cormorants. Examples are the decline in eel catches in the lakes of Schleswig-Holstein (Dauster 1987), a decline in zander catches in the Ijsselmeer (Osieck 1991), a decline in bream catches in the Netherlands (Veldkamp in press) and a decline in whitefish catches around the Apostle Islands in Lake Superior, Wisconsin, USA (Craven & Lev 1987).

In three of these examples, cormorant dietary studies have shown they did not eat the commercial species in question. In Schleswig-Holstein, cormorants feeding in freshwaters mainly eat small, shoaling noncommercial percids (Worthmann & Spratte 1990, Kiekbusch & Koop in press). On the Ijsselmeer, cormorants take mainly shoaling cyprinids and the decline in zander has been attributed to overfishing (Osieck 1991). In the Apostle Islands, cormorants were found to be feeding on small 'forage' species such as sticklebacks, sculpin and burbot. Only in Veldkamp's study did cormorants consume sufficient large bream to account for local decreases in catches.

In contrast there was an increase in the commercial catches of roach on Lake Neuchatel from 5 to 75 tons per annum over the 50 year period 1917 - 67, as wintering cormorants increased from 5 to over 100 over the same period (Suter 1991b). Roach and perch are the main food of cormorants on the larger Swiss lakes, and the increase in both wintering cormorants and commercial catches were probably the result of the increasing abundance of these fish accompanying eutrophication of the water.

In the absence of time-series data to compare changes in fish and bird abundance, many authors have attempted to assess the impact of cormorant predation by mathematical calculation. In most instances too little is known to incorporate the population dynamics of fish or birds. Consequently, the process merely involves the calculation of the consumption of fish by birds, comparing it against the commercial harvest, or as a proportion of the estimated standing stock of fish in the lake. For example, Van Dobben (1952) multiplied the number of birds thought to be using the Ijsselmeer, by their estimated intake over the summer (based on a daily adult intake of 400 g) and by the proportion that various foods occurred in the diet. In this way he calculated that cormorants annually removed about 7.5 million eels from the Ijsselmeer, of which no more than 5.6 million would have been harvested by humans in the absence of cormorants. This additional catch would have increased the average harvest of about 55 million, by about 10%. The consumption of zander by cormorants was calculated at 620,000 fish, which equated to a similar loss of about 10% to the fishery. Both these fish species are now less important in the diet of Ijsselmeer cormorants which feed on large shoals of perch, roach and ruffe. Despite an enormous increase in the numbers of cormorants, Osieck (1991) calculated that they now consume only 1.7% of the fish standing crop, and that the estimated impact on the current fishery is no more than 3.3% of the perch catch.

Other studies have estimated fish consumption by cormorants as 2 - 17% of the standing crop of fish in lakes (Linn & Campbell 1992, Martijn & Dirksen 1991, Veldkamp in press), or as 1.6 - 2.7% of the fish caught by man in the same area (Linn & Campbell 1992, Zimmermann & Rutschke 1991). None of these studies gave confidence limits to their estimates of bird numbers, diet, or fish abundance so it is difficult to judge the veracity of such big calculations. Even if all estimates were accurate, a mathematical modelling process needs to accommodate for such aspects as the sizes and ages of fish consumed, the potential for compensatory growth and decreased mortality of survivors, and the interaction between species within the fish community. None of the studies addressed these aspects.

3.3.4. Cormorants on rivers

On rivers, cormorants are commonly thought to affect fisheries by their consumption of large numbers of salmonid fish. In Eastern Canada, an apparent increase in cormorant numbers occurred at the same time as a decline in the rate of return of tagged salmon smolts (Kehoe 1987), but a large sample of shot birds showed salmon smolts were rare in the diet (0.1%). From the few smolt tags found, it was estimated that cormorants took about 0.2% of released smolt in 1986.

There have been several studies of cormorant diet in Britain and Ireland, where birds were shot on rivers and estuaries at the time of the smolt run to search for salmonids in their stomachs (Piggins 1959, Mills 1965, Rae 1969, McIntosh 1978, Kennedy & Greer 1988 and Carss & Marquiss in press). On estuaries, salmonids were unimportant in the diet except for a small sample of stomachs from one part of Ireland in May and June, which contained brown trout (Piggins 1959). Further upstream trout was often an important part of cormorant diet (Table 1), though most of the fish were small and well below the sizes kept by anglers (Table 2). On most of the rivers examined, salmon were not an important element in the diet, only rarely recorded in stomachs from estuaries, and in only few instances an important part of the diet further upstream. A small sample of birds from a river in northern Scotland contained mainly salmon, many of which were large enough to be smolts (Carss & Marquiss, in press). There was no information on the numbers of cormorants using this river and therefore no idea of the scale of the predation on juvenile salmon.

At two places in Ireland, there were estimates of the numbers of cormorants present and the consumption of salmon smolt was calculated by extrapolation. Kennedy & Greer (1988) estimated the predation rate of cormorants on smolts in the River Bush, Northern Ireland, by counting birds and multiplying up, using an intake rate of 425 g per bird per day, and an estimate of diet from the stomachs of shot birds. The stomachs of four birds from above a hatchery contained trout and some salmon smolts, but four birds from below the hatchery had only eaten hatchery smolts. The samples were small but it seemed that these cormorants ate mainly smolt and extrapolation suggested that 51-66% of 'wild' smolt and 13-28% of hatchery smolt could have been taken in 1986. The larger estimate for 'wild' smolt arose because of large counts of birds upstream from the hatchery, congregating in an area which had been intensively stocked.

MacDonald (1987b & 1988) conducted studies at a site in Co. Mayo, western Ireland, where cormorants also fed on salmon smolt. The methods of study were not reported in detail but predation rate was estimated from "information on activity (feeding, flying and resting), diet and feeding rate" as 5.8 - 13.1% of migrating smolts. The loss to the salmon harvest was thought not to be substantial because most of the fish taken were of hatchery provenance and experiments at this site had shown hatchery fish had a poor return rate compared with wild fish, perhaps because hatchery fish "show poor predator avoidance".

Another area of concern has been the predation of grayling by cormorants on large rivers in Switzerland where grayling populations are used for recreational angling and are sustained by artificial stocking (Staub 1987 & in press). There is conflicting circumstantial evidence of the effect of cormorant predation. Since 1983, grayling catches have declined as wintering cormorants have increased on rivers, most notably in one area where an influx of cormorants, shown to be feeding on mature grayling, was associated with a decrease in yield. At this site, 25% of spawning grayling had injuries thought to have been caused by cormorants. It was thought that predation here was additive leading to the reduction in older, more productive, year classes from the spawning population. In contrast, Suter (in press) points out the paucity of adequate evidence for predation effects, and that in a well documented case on the Rhine, predation by cormorants was positively correlated with yield. Here variations in the growth rate, age structure and age at first maturity were not related to cormorant predation, but to the presence of strong cohorts of young grayling (age 2), which itself determined the intensity of cormorant predation pressure.

Finally, there have been claims that the large numbers of cormorants on the River Ribble in northwest England are causing indirect damage to fisheries by affecting the behaviour of fish and making them less "catchable". It is reported that the cormorants have harassed fish so much as to drive them into the sidestreams where the fish cannot feed so well. The evidence for this is that large fish, some bearing scars resembling those inflicted by cormorant beaks, have been found in large numbers on tributaries of the Ribble that do not normally support such large fish (J M Davies pers comm). The situation is under investigation, but for the present the evidence remains anecdotal.

Also on the River Ribble, sport fishermen believe that cormorant predation reduces catches so they are reluctant to return to a fishery where they have seen birds fishing. Day ticket sales on some stretches of the Ribble have decreased in recent years and it is claimed that cormorant predation has in this case led directly to economic loss. In reality, it is prejudice that has led to economic loss. It may be that cormorant predation can reduce catches but this has still to be shown.

3.3.5. Summary of cormorant impacts

There is strong evidence that cormorant predation can lead to substantial losses at fish farms. However, such losses can be reduced using combinations of exclosures, deterrents and by changing the stocking regime.

There is only anecdotal and poor circumstantial evidence of cormorant predation effects elsewhere, but the lack of hard evidence is due in part, to the difficulties in manipulating cormorant predation levels in a controlled experiment. Studies of the stomach contents of shot birds have often contradicted anecdotal evidence. In other cases, quantitative estimates of fish consumption by birds, compared with fish standing crop, or with catch data puts bird predation in perspective. Unfortunately, the accuracy of these estimates is rarely given so they are difficult to evaluate. Indirect effects of cormorants harassing or stressing fish (or chasing them into suboptimal habitat) leading to poor feeding and growth, and making them less "catchable" are theoretically possible but the evidence for it remains anecdotal.

Two published examples with evidence suggesting substantial losses of smolt to cormorants, involved artificially enhanced salmon populations. The loss of grayling to cormorant predation in rivers also involved stocked fish. The somewhat poor evidence accumulated so far, suggests that losses to cormorant predation should be viewed as one of the costs of stock enhancement, rather than a natural phenomenon that demands control.

Areas that deserve further scrutiny include a quantitative study of cormorant predation at stocked stillwaters, particularly on smaller water bodies where the fish population can be estimated with some accuracy. There is also a need to compare the age, condition and parasite burden of fish consumed by cormorants with those taken by anglers, for they may not be targeting the same fish. Quantitative studies are also required on the predation of wild salmon smolt as opposed to those of hatchery provenance. An investigation into methods of reducing cormorant predation is required so that experiments estimating impact can be attempted. In the long term, a more useful experiment would be to vary stocking regime in an attempt to reduce the predation of valued fish at the expense of other, less valuable, populations.

3.4. The impacts of sawbill ducks on fish populations

3.4.1. Sawbill ducks at fish farms and stillwaters

Predation by goosanders and red-breasted mergansers is not considered a serious problem at fish farms (Carss 1989) or on stillwaters. Beach (1937) described the almost total loss of stocked fish from a small pond in Michigan that had been visited by goosanders during severe winter weather, but the evidence was anecdotal. Meigs & Rieck (1967) suggested from the stomach contents of shot goosanders and bird abundance, that they may have reduced rainbow trout stocks that had been introduced into lakes and rivers in Washington, USA. The evidence was circumstantial, poorly quantified and the situation was "somewhat clouded" by serious losses of fish to parasites and the effects of insecticides. Nevertheless several methods of goosander control were tried, including scarecrows, balloons and firecrackers to deter birds, and shotguns and gillnets to kill birds. There were no data given on the effectiveness of such methods.

The diet of goosanders on stillwaters in North America comprises mainly non-commercial species or 'forage' fish particularly gizzard shad in warm water wintering areas (Table 5). Miller and Barclay (1973) estimated the consumption of fish in one such site as 6.0 and 12.5% of the standing crop over the winters of 1971 and 1972 respectively. The consumption of fish by red-breasted mergansers, on a shallow saline lake in the Netherlands, was estimated at 36% of the standing crop of gobies and 11% of sticklebacks (Doornbos 1984). The consumption of fish by goosander and red-breasted merganser has also been estimated for two lakes in southern Sweden, but in the absence of details of their diet (Nilsson & Nilsson 1976, Winfield 1990). There is little information on the diet of goosanders on stillwaters in Britain.

3.4.2. Sawbill duck predation of salmonids in rivers

On the basis of their diet, goosanders were thought to eat sufficient juvenile salmon to reduce the catch of adult salmon in parts of eastern Canada, Scandinavia and Scotland (references in Table 5). Also on the basis of diet (Table 8), red-breasted mergansers were considered innocuous in all countries except Scotland, where their diet on some rivers included a high proportion of large salmon parr and small smolts. Further anecdotal evidence is provided by the aggregation of these ducks on the river in spring when salmon smolts are migrating downstream. However, the ducks aggregating on the lower river during the smolt run are feeding mainly on parr. Feltham (1990 & in prep) looked at stomachs of mergansers shot in different months and found they consumed large parr and a few small smolt. The high proportion of salmon in the diet was in April at the start of the smolt migration, other species of fish becoming important thereafter.

Recent investigations of stomach contents has widened the range of rivers sampled in Scotland.

On rivers in northern Scotland salmon is an important part of the diet of goosander and merganser in spring and of goosander ducklings in summer (Feltham 1990, Marquiss, Feltham & Duncan 1991, Carss & Marquiss 1992, Marquiss and Duncan 1993). In southern Scotland, adult sawbills ate far less salmon in spring and goosander ducklings ate almost no salmonids in summer (Marquiss & Carss unpublished, data in Murray 1992). This has ruled out any major impact of sawbill predation at some sites, but the problem remains unresolved at others. There, the question is whether the removal of large numbers of large parr, or small smolts from the start of the migration in April affects the subsequent numbers of adult salmon caught.

One way to resolve this uncertainty is by controlled experiment, by removing duck predation artificially and comparing the subsequent harvest of adult salmon with that from an area where ducks have not been removed. Such an experiment has not been achieved, mainly because of the difficulty in accurately estimating the numbers of returning adult salmon that are harvested. Nevertheless, some so-called experiments have been tried, removing ducks and recording the subsequent abundance of juvenile salmon. In Nova Scotia, White (1939) found twice as many salmon smolts following one year of bird removal, but there is large annual variation in smolt numbers and no parallel measurements of smolt output were made from places where ducks had not been removed. It was not possible therefore, to attribute the increase in smolts specifically to the removal of birds. In New Brunswick, Elson (1962) also failed to demonstrate an effect because his duck removal "experiment" ran concurrently with varying levels of artificial stocking. The results of preventing predation could not be strictly distinguished from an enormous increase in the number of hatchery fish released. Even if this experiment had been properly conducted, there would still be uncertainty about the effects of sawbill predation on wild salmon because it is known that hatchery fish are naive and particularly prone to predation by goosanders (Wood & Hand 1985) and other predators (see reviews in Wiley et al 1993 and Johnsson 1993).

A more recent experiment in New Brunswick (Anderson 1986) had a companion control area, but failed to demonstrate any effect. The number of ducks was reduced by 75%, but the large annual variation in fish densities meant that an increase in the numbers of juvenile salmon could not be demonstrated. This result could have come from an absence of any effect of duck predation, or it may have arisen because duck effects were there, but were small and easily masked by the effects of other variables. Irrespective of the mechanism it showed that management of ducks provided little if any gain. Anderson argued that the removal of ducks was cost-effective, but this was done on the basis of calculating the numbers of fish saved from predation using the numbers of ducks killed and an estimate of their diet. From the sketchy details given, it seemed that diet was not estimated properly. Moreover, the overall result of the experiment suggested few, if any, additional fish resulted from shooting ducks. A major problem was that although salmon harvest was estimated for the first part of the work, the harvest methods changed in the first year that an increase might have been expected, so that the effect of duck killing on harvest could not be determined. In retrospect this experiment was not the worst of failures; Erskine (1972) mentions three other goosander removal experiments that were aborted, or failed and have remained unpublished.

To date, no properly controlled duck removal experiments have been attempted in Britain. An alternative approach has been to assess the possibility of an effect of duck predation, by calculating the amount of fish consumed by ducks and thus the maximum potential losses to a fishery. In the absence of better information, the simplest of calculations merely multiplies the number of salmon eaten per duck per day by the number of ducks and by the number of days ducks are present on the river (Lindroth 1955, Lid & Schandy 1984, Carter & Evans 1986, Kalas *et al* 1993). The calculations for some river systems have been speculative because of a lack of information on sawbill diet (Roberts 1988, Howell 1987). However, even where diet is known, such estimates can be unrealistic because they take no account of variation in the survival of juvenile salmon associated with their age and population density.

The model used by Howell (1987) had some sophistication in that it allowed for the growth of fish and their overall probability of survival. He estimated that goosanders could have taken between 16 and 25% of the 1986 smolt production on the Afon Tywi (Wales), but also pointed out some major weaknesses in the model. The diet and food consumption of goosanders on the Tywi were unknown and had to be presumed from published literature. The magnitude of the smolt population was also unknown because of difficulties in measuring fish densities on the wider sections of river where goosanders mainly feed. Moreover the model may have been unrealistic because it assumed that predation by goosanders acted in addition to other sources of mortality, whereas it is more likely that it was offset by reduction in these other sources of mortality. Howell was correct to be cautious; work done since that time suggests average-sized smolt are unlikely to be a major part of the diet of goosanders anywhere, and that salmon may not be a major food of goosanders in Wales.

A calculation of sawbill predation on the River North Esk, Scotland (Carter & Evans 1986) was also handicapped by lack of accurate information on diet. This calculation estimated predation could have accounted for 10 - 24% of smolt production. Shearer et al (1987) modelled the same situation but with more information on fisheries catches. Average annual smolt production was estimated from capture and recapture of fin-tagged smolts, and some level of compensatory mortality was incorporated as, for example, fewer smolts going to sea might result in a greater proportion returning as adults. The resulting calculation estimated sawbill predation as removing between "a few" and 35% of salmon production.

These calculations assumed that ducks ate average size salmon smolt. However, since then, research on the sawbill population of the same river has shown that they consume more parr than smolt (Feltham 1990), and take them from the main stem of the river (Marquiss & Duncan 1993, and in press). The smolts consumed are also atypical fish in that they are mainly the smallest, and from the start of the migration (Feltham 1990; see also Kalas *et al* 1993).

Moreover, the fin-tagging procedure itself affects fish survival in a variety of ways (Reitan, Hvidsten & Hansen 1987, Hansen 1988, Kennedy, Strange & Johnston 1991), including in this case, the probability of predation by sawbills (Feltham, in prep). There is also circumstantial evidence that stock enhancement, using hatchery smolts, attracts sawbills and this could lead to unnaturally high predation of wild fish (Wood 1986 & 1987, Kalas *et al* 1993).

Nevertheless, studies of diet show that at least in a few sites, sawbills can take very large numbers of small salmon. Some small scale experiments currently underway on rivers in Scotland will help assess the potential impact by providing some empirical evidence of the effects of removing large numbers of small fish. However, this still leaves unresolved the issue of whether more small smolts will produce an equivalent increase in salmon harvest. In recent years, the mortality of salmon at sea has substantially increased and the timing of their return to freshwater has also changed (Shearer 1992, Ritter 1993, Turrell & Shelton 1993), introducing further complications to mathematical models of sawbill impacts on fish catch. Even if a model is produced that adequately takes account of fish population dynamics, it would require validation by reducing sawbill predation and confirming the predicted outcome in terms of fish harvest. The installation of fish counters to estimate the numbers of migrating salmonids provides a more accurate measure of adult return, so better designed bird removal experiments may now prove practical.

As yet, no work in Britain has been able to investigate the effect of sawbill predation on river trout fisheries because of the difficulty in distinguishing brown trout from sea trout smolts in duck stomachs. In theory, the removal of small trout from a river could be beneficial to a brown trout fishery by thinning out stock and so enhancing growth, whereas the removal of sea trout smolt could be detrimental. In addition, no research in Britain has properly addressed the potential effect of sawbill predation on coarse fisheries, although experimental work on this subject would be easier than on migratory species where sea mortality can be so great that significant bird effects are difficult to detect.

3.4.3. Summary of sawbill impacts

Dietary studies of goosander and red-breasted merganser have shown they consume small fish, which at most times of year and in most places are fish of no commercial interest. The circumstances under which sawbills might affect fishery interests are the exception rather than the rule. Some experiments have been attempted in eastern Canada but have failed to show any effect of duck predation on salmon stocks, mainly because of poor experimental design or procedure. Results from the best conducted experiment suggested that if an effect of sawbill predation existed, it was small compared with other factors affecting salmon abundance.

In Britain, sawbills can eat large numbers of small salmonids at some sites, but no properly controlled duck removal experiments have been done. Estimates of up to 35% loss in salmon catches from duck predation, have been shown to be based on invalid assumptions. Sawbill diet and abundance varies from river to river and could be influenced by stock enhancement and some fish-tagging procedures. Most of the juvenile salmonids eaten by sawbills are parr from the main stem of the river, and the smolts consumed are smaller than average and come from the early part of the smolt run. Modelling the effect of the removal of such fish requires a knowledge of salmon population dynamics that at present is incomplete. Any mathematical model that adequately takes account of fish population dynamics still requires validation, by reducing sawbill predation and confirming the predicted outcome in terms of fish catches.

As yet no research in Britain has properly addressed the potential effect of sawbill predation on river trout or coarse fish fisheries.

4. THE LEGAL PROTECTION OF CORMORANTS AND SAWBILL DUCKS.

4.1. Legal protection and licensed killing in Britain and Europe

4.1.1. Great Britain

Cormorants, goosanders and red-breasted mergansers are fully protected in Great Britain under the **Wildlife and Countryside Act 1981**, which implements the **European Community Directive on the Conservation of Wild Birds (EEC/79/409)**. The 1981 Act makes provision for the killing of birds by licenced shooting (section 16(1)(k)) *"for the purposes of preventing serious damage to .... fisheries"*. A further clause (section 4(3)(c)) provides a mitigating defence for the unlicensed shooting of birds, provided it is for *"preventing serious damage to ...... fisheries"*.

Each licence issued represents a **Derogation** under **Article 9** of the EEC Directive which allows deviation from the Directive where "serious damage" to fisheries occurs and where no other satisfactory solution can be found:-
Article 9 EEC/79/409

"member states may derogate from the provisions of Article 5, 6, 7, and 8, where there is no other satisfactory solution for the following reasons:
a) - in the interest of public health and safety
- in the interest of air safety
- to prevent serious damage to crops, livestock, forests, fisheries and water,
- for the protection of flora and fauna"

There is thus ample provision in both British and European law to allow measures to be taken where cormorants, goosanders or red-breasted mergansers are doing "serious damage" to the welfare or livelihood of people, or to conservation interests. The licensing authorities which deal with licence applications for the purposes of preventing serious damage to fisheries, are the Scottish Office Agriculture and Fisheries Department in Scotland, the Ministry of Agriculture Fisheries and Food in England and the Welsh Office Agriculture Department in Wales. Licences for the protection of flora and fauna, and those for the purposes of scientific research, are processed by Scottish Natural Heritage in Scotland, English Nature in England and the Countryside Council for Wales in Wales.

In theory, no licences need be currently issued in Britain to prevent "serious damage" to fisheries because there is no hard evidence for such damage. Furthermore, there is no hard evidence that shooting is effective in preventing damage, other than in small enclosed systems such as fish farms. Indeed, at such places managers can shoot birds to protect their livestock or fishery, relying for their defence, if prosecuted, on the mitigation clause (section 4(3)(c)).

In practice, fishery managers do not wish to take risks and prefer the security of a licence. Some licences have been issued in England for the killing of cormorants where there is circumstantial evidence of serious damage to stocked fish and where other means of solving the problem have been tried, and have failed. In Scotland, licences have been more readily issued to kill cormorants, goosanders and red-breasted mergansers, with conditions limiting the number of birds to be shot, specifying the time of year and requesting that carcases be returned to examine their stomach contents. Licences have been issued on the basis of the circumstantial evidence that these birds are abundant, and that they can eat stocked fish and wild salmon and trout. An attempt is made to issue licences for specific places where such evidence appears to be greatest; the presumption being that the consumption of large numbers of stocked fish, or juvenile salmonids results in serious damage to a fishery. However, a causal link between consumption and serious damage has certainly not been scientifically established and so the licensing authorities remain vulnerable to criticism.

In recent years scientific licences have been issued in Scotland to kill cormorants and sawbills to investigate diet but, no licences have been issued anywhere in Britain to protect flora and fauna for conservation purposes.

4.1.2. Europe

Elsewhere in Europe, cormorants and sawbills are similarly protected except by derogation (Article 9, in the EEC), or where they are deemed quarry species for hunting. Wherever and whenever the birds are protected, there is usually provision for killing or compensation in circumstances where there is fisheries damage, but no countries have specified criteria for such damage. Cormorants are widely perceived as damaging to fisheries, whereas sawbill ducks are only considered to have a potentially damaging effect in Norway, where some licences are issued annually for fisheries protection (Broughton 1991).

An analysis of questionnaire returns from 10 European countries (Gromadzka & Gromadski, in press) showed cormorants were everywhere perceived as damaging at fish farms and sometimes at other fisheries, but only by fishfarmers, fisherman or sport-fishermen. In most countries, serious damage was thought to occur only at fish ponds. Two countries, Germany and the Netherlands, provide financial compensation for damage. Scaring and killing was allowed in some circumstances in all countries, but in none could shooting be reported as effective in preventing damage. Only a few countries had addressed the issue with research or management plans.

In Sweden, shooting of cormorants is permitted year round within 200 m of static fishing nets, but following complaints from fishermen, a management plan is being devised (Lindell 1991).

Denmark is the only country so far that has actually produced a management plan (Asbirk, Appendix II) and this gives emphasis to preventing damage by scaring. Professional fishermen are allowed to kill cormorants at any time within 100 m of their fishing gear and the state is funding research to devise effective covers to protect pound nets. In Poland, shooting is allowed at fish farms and to deter new breeding colonies from becoming established nearby (Gromadzka & Przybysz 1991). A previous attempt in 1987 and 1988, to cull the population in fish farming areas by killing at breeding colonies, failed because surviving birds moved and bred well elsewhere (Gromadska & Przybysz 1991, Dobrowski & Dejtrowski, in press). In Germany, fish farmers can kill up to 8 birds per farm from July to December and compensation can be paid to lake fisheries (Menke 1991). In the Netherlands, the emphasis is on scaring and compensation has been paid to eel fisheries (Osieck 1991). In France, cormorants can now be killed at all fish farms (Marion, in press) but in Italy no licences are issued and illegal killing is commonplace. Illegal killing of cormorants was said to occur in almost all European countries, including those such as Sweden (Lindell 1991) where there is ample provision for legal killing.

In some countries, cormorants and sawbills are hunted as quarry species, within specified seasons. Cormorants are shot for sport in Iceland and Sweden, goosanders in France, Denmark, Norway and Estonia, and red-breasted mergansers in France, Iceland, Denmark, Norway and Estonia (Broughton 1991). In Iceland, the eggs of goosander and red-breasted merganser can be taken provided four are left in the nest, and the eggs and young of cormorants can be taken for food, though adults cannot be shot at breeding cliffs.

5. SERIOUS DAMAGE TO FISHERIES.

5.1. <u>What constitutes "serious damage to fisheries"?</u>

The term 'fisheries' includes not only the occupation or industry of catching fish but also the place associated with it. In freshwaters, fisheries can vary from a syndicate-run whole watershed river system, to a club-run angling stretch; from a commercial fish farm pond, or a small put-and-take sport fishery, to lake-based angling or netting operations. This diversity of operations has in common the use of fishery as an applied term to describe the exploitation of a fish population. The fish may be caught for recreation, harvested for food, or both.

One of the objectives of the present review was to address both the economic and ecological impacts of piscivorous birds on freshwater fisheries. The detrimental economic impacts of birds on freshwater fisheries can be measured as economic loss to a fishery. In contrast, detrimental ecological impact cannot be measured except against some benchmark that involves subjective value judgement. Suter (1991c) defined "ecological damage" as a "negative influence on the (fish) population resulting in long term decline". This definition is questionable because ecological systems are in flux; they can be complex or relatively simple, oscillating or relatively stable. An increase in piscivores at the expense of their prey is part of a natural process, and cannot be said to be damaging in purely *ecological* terms. However, it could be said to be damaging if we value one aspect of an ecological system above others.

Therefore, for the purposes of the present discussion, the term "detrimental ecological impact" is used within a conservation context and refers to the loss of something considered desirable in conservation terms, such as the 'naturalness' of a fish community, fish community diversity *per se*, fish productivity, or perhaps a rare or endangered native fish species. A prerequisite to measuring any "detrimental ecological impact" would therefore be some statement of what is considered desirable for the site of a particular fishery. The relevant measurements, for example of fish community, fish production or the abundance of a particular species, can then be defined and the appropriate data collected. The issue is at present academic for we know of no study that has shown cormorants, or sawbill ducks to be responsible for impoverishing an unstocked river or lake fish community, or endangering the future of a scarce native species.

5.1.1. Criteria for "serious damage" to fisheries

The Wildlife and Countryside Act 1981 allows that licences be issued "for the purposes of preventing serious damage to .... fisheries", but does not give criteria for "serious damage", or qualify it with description, or with examples.

It can be reasonably argued that damage refers to some sort of loss. In simplest terms, this might be the economic loss of a reduced fish harvest, or a reduction in angling catch leading to a reduction in ticket sales and economic loss to a fishery. Other types of loss may not be easily defined in economic terms if they involve, for example, a reduction in club members using a fishery, or lower catches per angler, but with no change in membership fee. Nevertheless, in every case loss should be measurable, though not necessarily in direct financial terms.

The point at which damage becomes 'serious' is more difficult to assess because it is subjective and will vary according to site and circumstance. Each fishery operation has its own economic circumstances such that a loss of for example 10% of fish stock may result in only slightly lower catches at one site, but the collapse of a marginally viable fishery at another, perhaps involving closure of a business and the loss of jobs. At both sites the loss of fish is the same but the subsequent economic damage is clearly more serious in the latter case. Measuring loss is therefore an essential starting point for assessing damage, but the seriousness of damage can only be judged using the appropriate context. Case law may eventually set guidelines for "serious damage" in financial terms where commercial fishery operations are concerned.

Irrespective of where precisely the line is drawn, damage cannot be considered 'serious' if it cannot be measured. Thus the criteria for "serious damage" must involve **measured** losses. Fish stocks can be measured by sampling, and fish harvest, angling catches, ticket sales or club membership can be measured directly. Provided this is done properly, 'damage' to a specific fishery can be quantified in terms of measured losses, and its 'seriousness' judged against the economic circumstances of that time and place.

To justify a licence to kill birds, however, not only has serious damage to be established on the basis of measured losses, but also these losses have to be shown to be the result of bird predation.

5.1.2. What evidence is required to establish that bird predation is responsible for losses?

As discussed in section 3.2. of this report, the only way to unequivocally demonstrate an impact of bird predation on fisheries is by experiment. At present, licences are issued on the basis of anecdotal and circumstantial evidence which is an inherently unsound procedure. Anecdotal information is subjective, while circumstantial evidence is often misleading, and almost always ambiguous or inconclusive. Nevertheless, it is impractical for every fishery with a perceived bird problem to do an experiment. The most efficient way to proceed would therefore be to conduct experiments in a variety of sites, thought to have bird problems. The results should establish the circumstances in which bird predation could result in serious damage, and thereafter individual cases could be assessed by analogy.

5.1.3. Does licenced killing prevent serious damage ?

Finally, given that there may well be circumstances where serious damage by birds occurs, there still remains the issue of whether licenced killing can effectively prevent such damage. Again, the issue is best tackled by direct experimentation. It has been argued that experiments investigating bird predation on fisheries are impractical and that it is difficult to get a clear answer. This is an invalid argument. Put simply, if birds are killed but a subsequent increase in fish abundance, fish catches or fishery harvest cannot be detected, then killing birds cannot be said to prevent *serious* damage. In such circumstances, killing cannot be considered to be cost-effective; it is a waste of resources and alternative practical remedies should be sought.

6. THE WAY FORWARD.

6.1. Suggestions for future NRA policy and research

In formulating future policy and identifying research requirements, the NRA should carefully consider the following:

(i) There is ample evidence that many people in many countries believe that fish-eating birds, particularly cormorants, adversely affect fishery harvest.

(ii) There is no hard experimental evidence that fish-eating birds seriously damage fisheries, nor that licenced killing effectively prevents damage.

(iii) The lack of such evidence does not necessarily mean that fish-eating birds do not have an effect, merely that to date the appropriate experiments have not been carried out. This situation reflects the expense and difficulty of such research work, as well as the poor design and procedure of some previous attempts.

(iv) The failure to carry out appropriate experiments has obliged the use of circumstantial evidence and anecdote in debate and in decision making. This in turn has lead to haggling and the polarisation of views, the issue itself remaining unresolved. This is both unsatisfactory and expensive.

6.1.1. Policy with respect to applications for licensed killing

The existing NRA position statement on cormorants and sawbills, formulated in 1992 (Appendix IV) shows that the Authority is fully aware of the concerns of fishing interests, but that in line with section 16 (1) (k) of the Wildlife and Countryside Act 1981, it cannot support shooting birds as a control measure unless serious damage to specific fisheries is proven and other deterrent methods have failed. In fulfilment of their statutory duties, the NRA has addressed the issue by implementing the current review.This extensive literature review has found no hard evidence that the killing of fish-eating birds prevents serious damage to fisheries. **Consequently it is recommended that there be no change in the current NRA position until such evidence accrues**. Support for the shooting of birds as a control measure could only be sanctioned if:

- serious damage to the fishery was established by measured economic losses;
- these losses could be attributed (directly or indirectly) to birds alone;
- other remedial measures had been tried and had failed, and
- it had been established that shooting would be effective in preventing the damage.

The most compelling evidence would derive from experimental work at that site or under similar circumstances elsewhere.

6.1.2. Recommendations for future research

In the light of the recommendation that there be no change in the current NRA position on shooting fish-eating birds without new information, it is recommended that future research proceed in one of three ways outlined below. All three options have advantages and disadvantages:

(i) Option 1 - To initiate no new NRA research but merely examine, through liaison with the licensing authority, each claim of bird damage as it arose, in the absence of any data collection. The advantage of this approach is that no specific NRA research or monitoring is required. Those with a fishery interest would have to pay for any research required to demonstrate "serious damage", to apply for a licence, or to defend killing if the use of the mitigation clause led to prosecution. The onus would clearly be with the licensing authority to initiate research to defend a policy of issuing licences.

The disadvantage of this approach is that it does not immediately address the concerns of anglers and fisheries managers, many of whom wholeheartedly believe that fish-eating bird predation is damaging fisheries. Consequently, the NRA could be accused of not fulfilling its statutory duty of maintaining, improving and developing fisheries. It could be reasonably argued that the duty of improving and developing fisheries need not be fulfilled if it required the killing of protected birds, as this would be at odds with the Authority's statutory duty to further conservation. Certainly, under this option, pressure from fishing interests will continue and the situation may remain unresolved, thereby prolonging conflict.

(ii) Option 2 - To limit NRA research to monitoring and the investigation of specific cases as they arise. This approach would be more expensive with the need to provide resources for monitoring fish and bird populations, and collating data for investigative casework. The option would fulfil the NRA statutory duties towards both fisheries and conservation and, in examining each case as it arose, would also address the concerns of the fishing interests lobby.

The main disadvantage of this option is that it could only truly resolve those cases where the circumstantial evidence ruled out serious damage by fish-eating birds; on the basis, for example, of no substantiation of losses, or where the consumption of fish by birds could not possibly account for measured losses. Many cases would remain unresolved, leading to protracted and wasteful debate. This option could only be used as an interim measure because some cases would arise again and again until the results of experimental work provided resolution.

(iii) Option 3 - To initiate (or promote in a supporting role) research to address the problem using an experimental approach, in anticipation of increasing claims of bird damage. The main advantage of this approach is in the chance of objectively resolving some long-standing problems once and for all. Depending on the study site, the results could eventually provide hard ('cause and effect') evidence to enable rational decisions regarding fisheries management and wildlife conservation at many sites under NRA jurisdiction. The option would properly address the concerns of fishing interests and would also fulfil the statutory duties of the NRA towards fisheries and conservation in a proper and positive manner.

The disadvantages of this approach are that it would be expensive (though the cost could be shared - see section 6.1.5) and would require long term commitment to specified management at one or more experimental sites. Only one specific fishery problem could be addressed at one time and place, and as with all such field experiments, the outcome might not be conclusive. In the meantime, the fishery interests will be impatient and individual cases will, in the short term, have to be handled using only circumstantial evidence, with its inherent problems.

It is recommended that the NRA adopts option 3.

6.1.3. The experimental research required

Two questions require answers:

(a) what mechanisms are the most cost-effective in *reducing* bird predation at a fishery?
(b) does bird predation have a *measurable* impact on fish stocks?

From the present review of the literature, it seems that in most instances, sawbills in England and Wales will prove to have little impact on fisheries. The most pressing demand is therefore for studies of cormorants, which could well cause losses, particularly of stocked fish on small 'put-and-take' fisheries, on larger stillwater sites and possibly on rivers. The best approach might be case-led with the important proviso that intensive work should only proceed where the financial resources are sufficient and the habitat is 'workable', so that the fish population can be monitored accurately. To this end, several cases may need to be investigated until a suitable candidate for intensive study arises. The ultimate objective should be the results from field experiments, but good experiments can only be designed if there is adequate background information. The process leading up to an experiment would therefore involve collecting the same sort of information that is required to investigate any claim of bird impacts.

The investigation should first look at both fish catches and fish abundance to see if they have declined. If neither have been measured any claim of bird impact is easily dismissed as unfounded. Fishery interests should be encouraged to collect 'fish catch' and 'fishing effort' data themselves, and fish population abundance (which need not be correlated with catches at all) needs to be monitored professionally for all important fisheries where it is thought problems might arise. If fish abundance cannot be measured, bird impact problems can never be resolved beyond doubt.

If fish population indices have declined as claimed, bird diet and abundance require estimation, and the potential fish consumption calculated. Provided these figures are of a magnitude consistent with the possibility of a detrimental impact on the fishery, an experiment may be feasible. However, the best method for manipulating bird predation would need to be resolved before an experiment commenced and consideration should be given to scaring as well as shooting. A control site, similar to the experimental site but where bird predation is not manipulated, is also necessary. Control and experimental sites need to be reversed as a second part to the study; bird predation being reduced at the control site, to compare with no manipulation on the original 'experimental' site during this second phase. The study sites, and sufficient finances need to be dedicated for the full term of the experiment. Previous 'experiments' investigating bird predation have failed because of changed protocol as the experiment proceeded.

To answer questions (a) and (b) above, it is recommended that the following controlled experiments should address:

(a) i) the effect of scaring techniques in reducing the number of cormorants using a site.

ii) the effect of shooting in enhancing 'non-destructive' scaring techniques.

iii) the effect of changing stocking regime (varying stocking density or adding 'low value' buffer fish) on the numbers of cormorants using a site.

(b) (i) the effect of reducing cormorant predation on fish abundance and harvest at a small 'put-and-take' fishery.

(ii) the effect of reducing cormorant predation on catches of coarse fish on rivers.

(iii) the effect of reducing cormorant predation on smolt output and adult harvest, on a salmonid river where there is no artificial stocking.

6.1.4. Other research and monitoring

In anticipation of bird predation problems, some financial support might be directed towards peripheral research as well as the national and local monitoring of fish and bird populations, their abundance, fecundity, mortality and movements.

Cormorants

(i) Cormorant subspecies.
It would be useful to know the origin of the cormorants using fisheries, particularly whether the birds are coming from continental Europe, and whether this represents potential change in the behaviour of birds here. This can be investigated by funding the colour marking of cormorants, through the British Trust for Ornithology (BTO), the Wildfowl and Wetlands Trust (WWT) and through the efforts of individual cormorant enthusiasts. The issue of cormorant subspecies would best be tackled using molecular genetic techniques by funding the work at an appropriate Institute or University. Large numbers of tissue samples (from carcases used to estimate diet in Scotland) have already been preserved in anticipation of such studies.

(ii) Choice of foraging sites by cormorants.
More needs to be known of the ways in which cormorants choose feeding sites. Work should concentrate on the relationship between fish availability, cormorant foraging success and their movements between sites, using colour marked birds and radio telemetry. The work needs to be funded at an appropriate Institute or University.

(iii) Prey selection by cormorants.
Within a fish population individuals vary in their size, age, condition and parasite burden and cormorants may select fish of a particular sort. A comparison of the fish taken by cormorants and anglers, with random samples from the fish population, will give estimates of selection, and the level of direct competition between birds and fishermen.

(iv) Cormorant diving patterns in relation to foraging.
Cormorant foraging success is related to their diving behaviour, which should be studied using telemetric techniques already pioneered by Wanless *et al* (1993), working on shags *Phalacrocorax aristotelis*. Comparative work, funded at the appropriate Institute or University may be the most cost-effective way forward here.

(v) The cormorant population needs to be monitored using census of breeding colonies and of wintering populations, paying attention to the accuracy of methods. This work should be done by the funding of existing national census organisations, the Seabird Monitoring Group, the BTO and the WWT.

(vi) Cormorant fecundity and mortality need to be studied to investigate the factors influencing population changes. This work requires nationwide sampling to monitor breeding success, and an analysis of ringed bird recoveries. Some data could be collected by amateur cormorant enthusiasts but the whole needs to be coordinated by the national organisations (above).

Sawbill ducks

(vii) Sawbill populations need to be monitored in winter, spring and summer, to detect trends in their numbers, distribution, breeding density and fecundity. The work requires widespread, sample monitoring and particularly for breeding birds this may prove practical only on a localised basis or as an intermittent widespread exercise. Funding of winter monitoring should be done through the existing National Wildfowl Counts and Birds of Estuaries Counts, organised by the WWT and the BTO. The same organisations should be approached to discuss the logistics of nationwide monitoring breeding numbers, distribution and success.

(viii) More information is required to predict sawbill abundance at particular sites and the effects of scaring or killing. Sawbill movements need to be studied in relation to fish availability, foraging success, bird density and scaring at specific sites. It is difficult to catch and colour-mark sawbills, and very difficult to estimate foraging success, so research here might not be easy. Some preliminary work might be funded at an Institute or University.

(ix) There is only sparse information on the diet of sawbills and cormorants on rivers in England and Wales. Extrapolation from dietary studies elsewhere is possible but it would be best to directly estimate the diet of birds at those sites where damage is claimed. If it were necessary to kill birds for stomach samples, scientific licences would be required from English Nature or the Countryside Council for Wales. The laboratory analysis of stomach contents could be commissioned from an Institute or University.

Monitoring numbers

(x) Sawbill and cormorant numbers need to be monitored locally wherever a fishery perceives a threat. The national organisations, Institutes and Universities can do this sort of work but consideration should be given to counts coordinated and carried out cooperatively by local fishery and bird interests, guided by a professional ornithologist. Such a procedure has been adopted successfully on the River Tweed. The Tweed area also has a useful catchment discussion group - the Tweed Forum.

It is recommended that the NRA considers supporting these studies on a case-by-case basis

6.1.5. Who should pay for the research ?

Sections 6.1.2 - 6.1.4. identify research to be done, but it is beyond the remit of research contractors to recommend how it might be funded. Fisheries interests claim they have a problem and it could be argued that they should pay for research to demonstrate the problem truly exists. The authorities that issue licences need to defend their actions and should therefore pay for research to show that the issue of licences does indeed prevent serious damage to fisheries. The NRA has statutory duties towards maintaining, improving and developing fisheries as well as to further conservation. This remit demands detailed knowledge of fish-eating bird/fisheries interactions, to make decisions in specific instances where differing statutory duties might demand conflicting management options. English Nature and the Countryside Council for Wales require knowledge to fulfil their statutory duty to advise on the issue of licences. Voluntary nature conservation organisations also require knowledge to argue their own case.

All the parties mentioned above need some research done. At present resources, are squandered in haggling over anecdotal and circumstantial evidence. It is clear that all parties have a vested interest in pursuing research that might resolve issues rather than prolong the debate. **Consequently it is recommended that all parties consider the long term view, that money spent on well conceived and properly conducted research will ultimately be recuperated in better informed, more efficient resource management.**

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APPENDIX I

Details of Fishes Mentioned in the Text

Many of the species described below have been extensively introduced by man for the purposes of sport fishing and aquaculture. Letters E = Europe and NA = North America therefore refer to continents of origin rather than actual global distribution. Details taken from Wheeler (1978) and Page & Burr (1991).

LAMPREYS - Family Petromyzonidae. The major group of truly primitive fishes, they lack jaws, fin rays, paired fins and scales. Long, eel-shaped fishes.

River Lamprey *Lampetra fluviatilis*. Migratory lamprey, adults leaving estuarine and inshore waters to spawn in rivers and streams. Up to 50cm long. (E)

Brook Lamprey *L. planeri*. Non-migratory lamprey living in small streams and the upper reaches of rivers. Up to 25cm long. (E)

EELS - Family Anguillidae. Elongated fishes with long dorsal and anal fins which often merge with the caudal fin.

European Eel *Anguilla anguilla*. Breed in the Sargasso Sea, larvae drift in currents to Europe where they metamorphose into elvers and ascend rivers. Grow to adulthood in almost all freshwater systems before maturing into silver eels, descending rivers and returning to Sargasso to breed. Males up to 50cm long, females to 100cm. (E)

American Eel *A. rostrata*. North American representative of Anguillidae, very similar in appearance and habits to the European Eel. Up to 152cm long. (NA)

HERRINGS - Family Clupeidae. Around 200 species of true herrings, most are marine fish which usually swim in shoals near the surface and in coastal waters.

Herring *Clupea harengus*. Extremely abundant shoaling marine fish, often found inshore when young. Up to 43cm long. (E, NA)

Alewife *Alosa pseudoharengus*. Anadromous: enters freshwater from the sea to spawn although there are many land-locked populations. An open water marine species occurring off the Atlantic coast. Usually less than 25cm long. (NA)

Gizzard Shad *Dorosoma cepedianum*. A midwater schooling fish found in deep rivers and lakes. Up to 52cm long. (NA)

Shad *Alosa spp.* Several species, typically marine. (E, NA)

WHITEFISHES - Family Coregonidae. Related to the salmon family and like them have an adipose fin. Coregonus spp. are widespread in Europe and north America. Populations are often isolated between watersheds making taxonomy complex and specific identification very difficult. Usually 20-50cm long. (E, NA)

SALMONS - Family Salmonidae, essentially northern hemisphere fishes. Members of the family live in freshwater but many species make feeding migrations to the sea. Family includes European salmons, trouts and charrs and also the **PACIFIC SALMONS** (*Oncorhynchus spp.*) of North America.

Atlantic Salmon *Salmo salar*. Widely distributed. Juveniles grow in freshwater before migrating as SMOLTS to the sea where they feed and return to their natal rivers to spawn after one year (as GRILSE) or several years (as SALMON). Most adults die shortly after breeding but some post-spawning fish (KELTS) may survive longer and even return to breed in subsequent years. Juveniles up to about 20cm, adults up to 150 cm long. (E)

Pink Salmon *Oncorhynchus gorbuscha*. A small salmon found in the sea and coastal streams. Adults up to 76cm long. (NA)

Kokanee Naturally occurring freshwater form of the Sockeye Salmon *O. nerka* a Pacific Salmon. (NA)

Brown Trout *S. trutta*. Extremely abundant in all types of unpolluted waters but requires cool, well aerated conditions. Resident throughout the year. Up to 30cm long in small streams but may reach 100 cm in length in larger lakes and rivers. (E)

Sea Trout - *S. trutta*. Migratory form of the brown trout. Juveniles leave freshwater as SMOLTS and return after one, or several years, to breed. Adults up to 140 cm long. (E)

Rainbow Trout *O. mykiss*. Originally an inhabitant of headwaters, streams and small to large rivers and lakes of Pacific North America. Widely redistributed as a sport fish and for aquaculture purposes. Up to 110 cm long. (NA)

Arctic Charr - *Salvelinus alpinus*. Mostly lives in high mountain lakes, two physiological types; one migratory the other resident. Most no more than 25cm long. (E, NA)

Brook Trout - *Salvelinus fontinalis*. A charr found in small streams, rivers and lakes. Up to 70cm long. (NA)

GRAYLINGS - Family Thymallidae. Often confused with true salmonids as they possess an adipose fin. All four species instantly recognisable by their large dorsal fins.

Grayling *Thymallus thymallus*. Essentially a river fish but also found in mountain lakes. Feeds mainly on the bottom. Juveniles may shoal, as do adults at spawning time. Rarely more than 50cm long. (E)

SMELTS - Family Osmeridae. Small relations of salmon and trout species, rarely more than 30cm long. Basically marine coastal fishes, many entering rivers and spawning in freshwater.

Smelt *Osmerus esperlanus*. An inshore migratory fish, most common close to river mouths and in estuaries. Enters rivers to spawn in winter. (E)

Capelin *Mallotus villosus*. Extremely abundant in the Arctic waters of the North Atlantic. Up to 23cm long. (E, NA)

PIKES - Family Esocidae. Long-bodied predatory fishes, five species.

Northern Pike *Esox lucius*. Inhabits lowland rivers and lakes, associated with submerged marginal vegetation. Widely introduced by man. Up to 130 cm (E, NA)

CARPS - Family Cyprinidae. The major group of freshwater fishes in Europe, also an important constituent of the fish fauna of North America, Asia and Africa.

Roach *Rutilus rutilus*. Common in lowland rivers and lakes. Can survive in mildly polluted waters. Average size of adults is 35cm long. (E)

Bream *Abramis brama*. Inhabits slow flowing rivers, lakes and ponds and also brackish waters. Shoals, feeds mainly on the bottom, often at night. Adults average 40-50cm. (E)

Rudd *Scardinius erythrophthalmus*. Lives in lakes and the backwaters of rivers, small ponds and canals. Forms shoals near the surface or in midwater. Up to 30cm long. (E)

Tench *Tinca tinca*. A fish of stillwaters but occasionally found in the lowland reaches of rivers. Mostly a bottom feeder. Can be used as a supplementary crop fish at Carp ponds. Up to 70cm long, but many populations are smaller. (E)

Carp *Cyprinus carpo*. A species of lowland lakes and rivers where there is abundant aquatic vegetation. Also farmed in ponds throughout much of the world. Mostly a bottom feeder, active at night. An adult average length of 50-60cm. (E)

Silver/White Bream *Blicca bjoerkna*. Found in slow flowing, lowland waters. Feeds on the bottom and in midwater. Up to 25cm long. (E)

Chub *Leuciscus cephalus*. Most abundant in the middle reaches of rivers and large lakes, shoaling when young. On average, 30-50cm long. (E)

Minnow *Phoxinus phoxinus*. Typically a fish of the upper reaches of rivers. Shoals at or near the surface in summer, moves to deeper water in winter. Rarely more than 8cm long. (E)

Dace *Leuciscus leuciscus*. Typically found in the middle reaches of rivers and streams, but sometimes in lakes. Forms large shoals in mid/surface waters. Generally 15-25cm long. (E)

Grass Carp *Ctenopharyngodon idella*. A native of China, feeds entirely on vegetation. Widely introduced, widespread as an aquaculture species. Up to 120 cm long (E)

Common Shiner *Luxilus cornutus*. Small fish inhabiting rocky streams and small rivers. Up to 10cm long. (NA)

Emerald Shiner *Notropis atherinoides*. Small fish of medium to large rivers and lakes, particularly over sand or gravel. Up to 13cm long. (NA)

Blacknose Dace *Rhinichthys atrutulus*. Found in rocky streams and small rivers. Up to 10cm long. (NA)

Lake Chub *Couesius plumbeus*. Can be found in any freshwater body, mostly in association with rocks. Up to 23cm long. (NA)

Fallfish *Semotilus corporalis*. Inhabits stoney-bottomed small to medium sized rivers and lakes. Up to 51cm long. (NA)

LOACHES - Family Cobitidae. Small, mostly slender-bodied fishes, related to the Cyprinids. All live in freshwater.

Stone Loach *Neomacheilus barbatulus*. Common in small rivers and gravel-shored lakes. Active at night and in dull light. Generally about 10cm long. (E)

SUCKERS - Family Catostomidae. 63 species in North America. Barbel *Barbus barbus* - like fishes with large thick lips. Feed on the bottom, often very abundant (NA)

White Sucker *Catostomus commersoni*. Found in small streams to medium rivers, Bottom feeder. Up to 64cm long. (NA)

COD FISHES - Family Gadidae. These fishes are, with one exception, all marine, mostly found in cool temperate waters of the northern hemisphere.

Cod *Gadus morhua*. Widely distributed in a variety of habitats from the seashore line to 600m deep. Average adult size is 120 cm (E,NA)

Pollack *Pollachius pollachius*. Widely distributed, particularly in inshore areas. Swims in shoals. Usually around 50cm long. (E)

Saithe *P. virens*. Widely distributed in the North Atlantic where it swims in large shoals. Average size is 70-80cm. (E, NA)

Burbot *Lota lota*. The only freshwater Gadoid. Found in the lowland reaches of rivers and the flood plains of lakes. Sedentary, most active in the evening and at dawn, mainly a bottom-feeder. Most commonly about 50cm long but grows up to 100 cm (E, NA)

KILLIFISHES - Family Fundulidae. Small (less than 20cm long), brightly coloured fishes found in fresh, brackish and saltwaters. (NA)

EELPOUTS - Family Zoarcidae. Found in cool, temperate polar seas both in the Antarctic and the Arctic. (E)

Eelpout *Zoarces viviparus*. Common seashore fish down to 40m deep. Found on rocky shores amongst algae and in deeper waters on mud and sand. Usually grows to about 30cm. (E)

SAND-SMELTS - Family Atherinidae. A large family of small fishes, widely distributed in tropical and warm temperate seas world-wide.

Sand Smelt *Atherina presbyter*. Common inshore and estuarine fish, abundant on sandy and rocky bottoms. Up to 21cm, but mostly about 15cm long. (E)

STICKLEBACKS - Family Gasterosteidae. Small fishes common across the temperate regions of the northern hemisphere. Some are marine, others confined to freshwater, but most thrive in both salt or freshwater and are often abundant in brackish conditions.

Three-spined Stickleback *Gasterosteus aculeatus*. Very widely distributed and often abundant in lakes, rivers and coastal waters. Mostly about 5cm, occasionally to 10cm. (E, NA)
Nine-spined Stickleback *Pungitius pungitius*. Widely distributed but local. Found in fresh and slightly brackish densely-vegetated waters. Usually less than 5cm but grows up to 7cm long. (E, NA)

SCULPINS/COTTIDS AND BULLHEADS - Family Icelidae and Cottidae. More than 300 species. Exceptionally abundant fishes, well distributed in the shallow seas of the northern hemisphere particularly in the north Pacific. A few species found in freshwater. Stout-bodied with broad, spiny heads. Usually less than 20cm long.

(Long-spined) Sea Scorpion *Taurulus bubalis*. Common fish on rocky seashores and in the sublittoral zone. Up to 17cm long. (E)

Bullhead *Cottus gobio*. Small freshwater fish. Abundant in streams, small rivers and larger lakes with stoney bottoms. Active at night. Usually not more than 10cm long. (E)

SEA BASSES - Family Percichthyidae. Spiny-finned fishes found world-wide in both tropical and temperate freshwaters, and in the sea.

(Sea) Bass *Dicentrarchus labrax*. Common coastal sea fish, forming shoals in inshore waters. Up to 60cm long. (E)

AMERICAN SUNFISHES - Family Centrarchidae. Freshwater fishes originally confined to North America. Most are deep-bodied species

Rock Bass *Ambloplites rupestris*. Inhabits the lower reaches of rivers and rocky bottomed shallow lakes. Up to 43cm long. (NA)

Small-mouth Bass *Micropterus dolomieui*. Prefers open waters with rocky or sandy bottoms, particularly lakes. Widely introduced in Europe. Up to 69cm (NA)

White Bass *Morone chrysops*. Common in lakes, ponds and in the pools of small rivers. Up to Up to 45cm long. (NA)

White Crappie *Pomoxis annularis*. Found in sand and mud-bottomed pools of small to large rivers, ponds and lakes. Up to 53cm long. (NA)

Sacramento Perch *Archplites interruptus*. Inhabits vegetated pools in slow-flowing rivers and lakes. Up to 73cm. (NA)

PERCHES - Family Percidae. Freshwater fishes with two dorsal fins, bodies covered with rough-edged scales. The family is best represented in North America where numerous small species (the **DARTERS**) live.

Perch *Perca fluviatilis*. Common fish in lowland lakes and rivers, forms shoals when young and when breeding. Usually about 35cm long but up to 51cm (E)

Ruffe *Gymnocephalus cernuus*. Inhabits lowland rivers and lakes. Lives close to the bottom in small shoals. Usually about 15-18cm long, exceptionally up to 30cm long. (E)

Zander *Stizostedion lucopercia*. A native of eastern Europe but introduced elsewhere. Lives in large lakes and lowland rivers, preferring cloudy water and avoiding weeds. Feeds close to the bottom, forming shoals when young. Usually about 60cm, but up to 130 cm. (E)

Yellow Perch *Perca flavescens*. North American species very closely related to, if not the same species as, the Eurasian Perch P. fluviatilis. Up to 40cm long. (NA)

GREY MULLETS - Family Mugilidae. A large family of mainly marine fishes.

Thick-lipped Grey Mullet *Chelon labrosus*. Common inhabitant of coastal waters of all Europe. Up to 75cm long

Thin-lipped Grey Mullet *Liza ramada*. Mostly a coastal species but penetrates well into rivers. The most abundant grey mullet in freshwaters in Europe. Up to 60cm long (E)

WRASSES - Family Labridae. Contains some 600 species, all of which are marine. Most are relatively small, shorter than 30cm long

ARCTIC BLENNIES - Families Stichaeidae and Pholidae. Small (>25 cm), long-bodied sea fishes of northern latitudes.

Butterfish *Pholis gunnellus*. Abundant coastal marine fish of the N. Atlantic, from the tidal area down to 100m, living amongst weed and stones. Up to 25 cm long.

SANDEELS - Family Ammodytidae. Rather small marine fishes found mainly in the northern hemisphere and most abundantly in the North Atlantic. They burrow in clean sand and shell grounds but also swim actively in huge shoals.

GOBIES - Family Gobiidae. One of the most successful families of bony fishes in all types of water. Typically small fishes, mostly 4-15cm long.

Black Goby *Gobius niger*. Widely-distributed on muddy or sandy bottomed sea shores. Up to 17cm. (E)

FLATFISHES - Family Scohthalmidae (left-eyed flatfishes) and Family Pleuronectidae (right-eyed flatfishes). During metamorphosis from postlarva to bottom-living young, one eye moves over the head. Reversed examples are very common in some species.

Plaice *Pleuronectes platessa*. Abundant bottom-living flatfish. Usually up to about 50cm long (E)

Dab *Limanda limanda*. Small, abundant flatfish. Up to 25cm long (E)

Flounder *Platichthys flesus*. Widespread marine flatfish living from the tide line to 55m deep. Also penetrates into freshwater, Up to 51cm. (E)

APPENDIX II

Denmark's Cormorant Management Plan

Management plan for Cormorants in Denmark

The population of breeding Cormorants has expanded exponentially during the last 10 years, and the number of complaints of damages has risen. This is the reason why the Danish National Forest and Nature Agency has decided to make this management plan.

Two subspecies of Cormorants occur in Denmark. The subspecies of Phalacrocorax carbo sinensis is breeding, while the subspecies of Phalacrocorax carbo carbo is a winter visitor.

The Cormorant has been breeding in very fluctuating numbers in Denmark. Due to persecution it has not been breeding for long periods. The period from 1876 to 1938 was the latest period without breeding Cormorants in Denmark. Since 1938 the Cormorant has been breeding in rather low numbers (a few hundred) at a few localities. During the last 10 years the population has risen from about 4000 pairs in 1982 to about 29000 pairs in 1991 (see table 1) mainly due to a ban on hunting. About half the Northwestern European population of Cormorants is breeding in Denmark (see table 2).

The Cormorant breeds in trees and on the ground on small treeless islands. The breeding distribution is seen in figure 1.

The food of Cormorants nearly totally consists of fish. In the 1940´ies 22% of the food were eels, while this fish species only made up less than 2% in 1980.

Most of the Danish Cormorants migrate southwards during the winter period.

Nowadays, it is not allowed to hunt or shoot the Cormorant in Denmark due to the EEC Bird Directive.

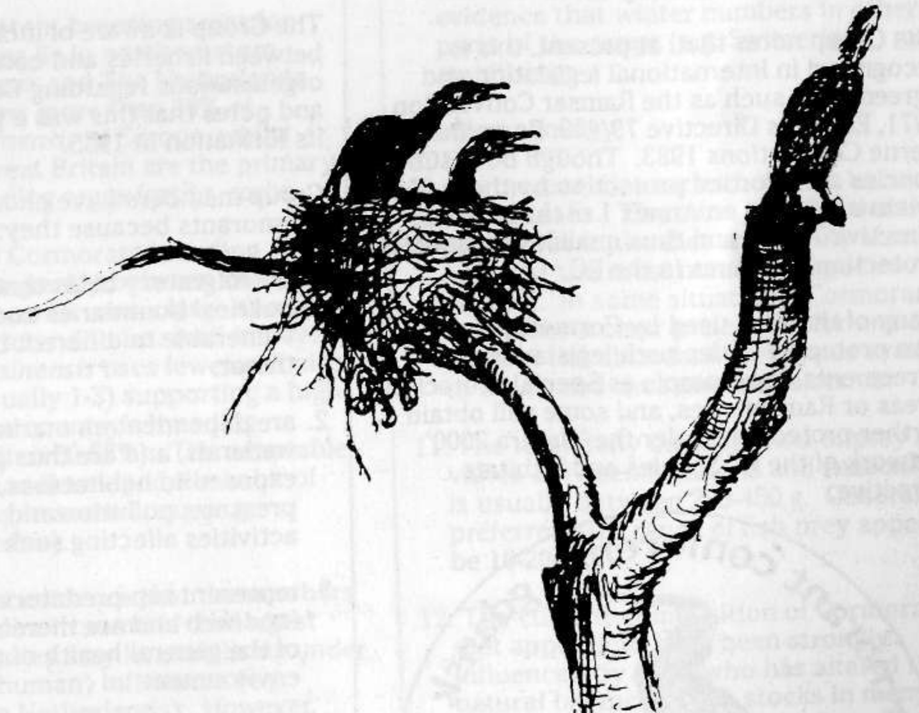
The Cormorants may damage the trees of their breeding colonies, the vegetation of the small breeding localities on islands, and they may damage or eat the catch of the fishermen. In order to prevent some of the damages it has been tried to regulate the size and the distribution of the colonies by shooting the big nestlings on or near their nests. The Cormorants may also be scared away from a locality or from fishing gear, pound nets etc. by shooting, gas cannons etc.

The management plan recommends that the establishment of Cormorant colonies as far as possible is accepted in those areas, where they have the best natural living conditions in Denmark. The breeding population is vulnerable to persecution in the colonies. In respect of the EEC Bird Directive hunting is not allowed. Professional fishermen with open pound nets should try to prevent the damage of the Cormorants by covering the pound nets with "bird nets" or by using gas cannons etc. As a supplementary help the professional (but not the amateur) fishermen should be allowed generally to scare away the Cormorants by shooting within a distance of 100 metres from their fishing gear. The same conditions should also apply to owners of fish ponds.

Foresters should accept the Cormorants, although they in special cases may be granted an exemption to scare away the Cormorants by shooting early in the breeding season, if the Cormorants establish colonies in very valuable or very vulnerable stands.

Owners of small islands, which may attract a breeding colony of Cormorants, should accept the establishment of the colony, unless national or international nature conservation values are threatened. In such cases they may be granted an exemption to scare the Cormorants.

The management plan will be revised in 1996/97.



APPENDIX III

Position Statement concerning Cormorant Research, Conservation and Management, Gdansk 1993

Drafted at the 3rd international meeting of the Cormorant Research Group, 13-17 April 1993, Gdansk, Poland.

FOLLOWING on from meetings in Sweden (1985) and The Netherlands (1989), the third international meeting of the **Cormorant Research Group** was held in Poland and was attended by 109 participants from 20 countries: Austria, Belorussia, Belgium, Bulgaria, Czech Republic, Denmark, Italy, France, Germany, Latvia, Lithuania, Norway, Poland, Portugal, Rumania, Sweden, Switzerland, The Netherlands, Ukraine and United Kingdom. A total of 70 papers was presented by leading experts on Cormorants, particularly those studying the two sub-species in Europe, *Phalacrocorax carbo sinensis* and *P. c. carbo*.

The Group has always been aware that the Cormorant is an ecologically important species that is highly dependent on wetland habitats and is especially vulnerable when concentrated in breeding colonies. The Group believes that the countries which share Cormorant populations should protect them, and the habitats that they use.

The Group notes that, at present, this is recognised in international legislation and agreements, such as the Ramsar Convention 1971, EC Birds Directive 79/409, Bonn and Berne Conventions 1983. Though both sub-species are afforded protection by these, *P.c. sinensis* is listed on Annex 1 of the EC Birds Directive 79/409 and thus qualifies for special protection measures in the EC.

Many of the sites used by Cormorants are also protected under such legislation and agreements, for example as Special Protection Areas or Ramsar sites, and some will obtain further protection under the 'Natura 2000' network of the EC Species and Habitats Directive.

The Group exists primarily to stimulate and coordinate research on all biological and ecological aspects of the species, to collate relevant data and to disseminate the results. The Group is conscious of the need to base management actions on sound scientific principles and findings.

The Group is aware of increasing conflict between fisheries and conservation organisations regarding Cormorant damage, and notes that this was a principal reason for its formation in 1985.

Group members have chosen to study Cormorants because they:

1. are migratory birds that move between political boundaries and have long been vulnerable to different types and degrees of threat;

2. are dependent on marine and freshwater wetlands, and are thus particularly exposed to habitat loss, changes in hunting pressure, pollution and other human activities affecting such habitats;

3. represent top-predators in the ecological food-web and are therefore good indicators of the general health of the water environment;

4. depend on fish and thus impinge on human interests, either commercial or social, giving the potential for real and perceived conflicts amongst fishermen, fishery managers and bird/nature conservationists.

The key findings of the Group to date, as discussed at the Gdansk conference, can be summarised as follows, further details being available directly from the Group, or from its publications:

Population status and trends

1. Cormorant populations have expanded greatly during the last 10-15 years from levels that were previously held low by man. There is still strong population growth in some areas, especially in the northern parts of the European range of *P.c. sinensis*, and the beginnings of (possible) sharp population increases are evident in central European areas also, such as Lithuania and Bulgaria.

2. In 1992, the European breeding populations were estimated at 105,000 pairs for *P.c. sinensis* and 45,000 pairs for *P.c. carbo*. This is the first European-wide estimate for *P.c. sinensis*, whose north-central European population alone rose from 40,000 pairs in 1988 to 77,000 pairs in 1992, a 93% increase. Census data for *P.c. carbo* from the same period are less complete, but the population increased by less than 20% during this time.

3. The most important breeding areas for both sub-species lie in north-western Europe. Denmark and The Netherlands together support more than 50% of breeding *P.c. sinensis* in Europe, whilst Norway and Great Britain are the primary European breeding areas for *P.c. carbo*.

4. The number of Cormorant breeding colonies varies greatly between countries. In general, *P.c. carbo* uses a large number of colonies, which tend to be small in size. In contrast, *P. c. sinensis* uses fewer colonies, with some (usually 1-3) supporting a high proportion of a country's breeding population (often 50-66%). The adaptable *P. c. sinensis* has developed the habit of ground-nesting in some areas (e.g. Denmark, Sweden).

5. There is recent evidence that the numbers of breeding pairs in some of the largest breeding colonies may be stabilising under natural (non-human) influences (e.g. Denmark, The Netherlands). However, there is strong evidence also to indicate that the populations of both sub-species are still likely to increase. This is because new colonies are forming, and there is much apparently suitable habitat not yet occupied.

6. Under natural circumstances, young birds appear to be most important in the formation of new breeding colonies. There is evidence that movement between colonies by established breeders is relatively uncommon, and occurs mainly in response to human disturbance.

7. Winter numbers have increased in accordance with increases in the breeding populations, and 1992/93 estimates for the winter period indicate the presence of at least 150,000 *P. c. sinensis* and 120,000 *P.c. carbo* in Europe. However, these data are known to be incomplete and thus provide minimum estimates.

8. Currently, the most significant wintering areas in Europe for *P.c. carbo* are Norway, France and Great Britain. For *P. c. sinensis*, France, Italy and Spain, collectively supporting more than 50% of the population, are the primary wintering areas in western Europe.

9. Whilst new, potentially important, wintering areas are developing in central and eastern Europe, there is recent evidence that winter numbers in other parts of the range (e.g. Switzerland) may be stabilising.

Feeding ecology

10. Cormorant diet varies between locations and seasons. The most abundant of the prey types in the diet are usually also amongst the most numerous species present. In some situations, Cormorants may show a clear preference for one or more of the abundant prey types available to them, and thus may be selective.

11. The total daily consumption of prey taken varies between locations and seasons, but is usually between 250-450 g. Generally, the preferred size range of fish prey appears to be 10-20 cm.

12. The current composition of Cormorant diet appears to have been strongly influenced by man, who has altered the natural balance of fish stocks in many situations (e.g. a reduction of predatory fish in the IJsselmeer, The Netherlands); increases in the biomass of Roach in Switzerland; stocking with trout in Great Britain.

13. Cormorants appear adaptable with respect to their fishing strategies. For instance, social-fishing has developed in several countries.

Impact on fish stocks and fisheries

14. Fishery interests in most European countries believe that Cormorants cause damage to fish stocks and fisheries.

15. Impact by Cormorants on fisheries may be of several, inter-related, types: economic (causing loss of income), ecological (effecting habitats, other species or ecotypes) or behavioural (affecting fish behaviour, and hence harvest rates, or the behaviour of fishermen themselves). This distinction has not always been made clear in reported cases of damage, and ecological and behavioural impacts have been little studied.

16. Relatively large losses of fish to Cormorants at individual fisheries have been demonstrated in a number of countries, mainly in extensive fish-farm areas and in the vicinity of fishing gear in lakes and coastal bays. However, the precise economic significance of such damage has rarely been quantified.

17. No significant impact by Cormorants, leading to large reductions in entire fish populations, has been demonstrated under natural conditions (i.e. in natural habitats and at natural fish densities).

18. Cormorant impact is generally most significant in artificial situations, for example where fish are farmed at high density.

19. It is recognised that injury to individual fish may be important in some situations, perhaps reducing the survival and growth of fish, or reducing the economic value of the stock. However, such effects have yet to be demonstrated.

Current and future management

20. A comprehensive population model, incorporating 'bottle-necks' and mechanisms for population expansion, is currently not available for the Cormorant. Thus, management actions are based on local knowledge only, and consequently the outcome of such measures is uncertain, especially in a European-wide context.

21. Shooting and other scaring techniques are already employed in many countries, though the success of these practices has rarely been documented. In many cases, this is believed to transfer the problem to other locations.

22. There are generally no precise guidelines or criteria applied to assess the scale of alleged damage to fish stocks and fisheries.

23. Whilst illegal persecution of Cormorants occurs in many countries, the scale of this is usually unknown.

24. There is growing pressure in many European countries to control Cormorants at the national level.

25. Only Denmark has an official, national, management plan for Cormorants.

The Group wishes to make maximum use of existing valuable but dispersed information, and notes that the most effective and economic means of collating existing data and gathering critical new data is through the coordination of activities of both amateur and professional researchers throughout Europe.

The following were identified as the principal gaps in current knowledge relating to Cormorants, and the Group hopes that these be recognised as priority research areas for the immediate future:

1. Fish population studies. Including research on fish population dynamics, particularly the role of Cormorants compared to other factors.

2. Impact studies. Detailed studies at different fishery types, and in a range of situations.

3. Damage alleviation. Research into measures (including protective and management) that minimise impacts on fish stocks and fisheries where these occur.

4. Cormorant behaviour. Particularly research into how Cormorants respond to regulation attempts, and the consequences of such actions with respect to numbers and distribution.

5. Habitat selection. Identification of the key factors influencing the selection of breeding, roosting and feeding sites.

6. Individual marking programmes. To allow further quantification of movements, mortality/survival, immigration and emigration. Especially needed in central and eastern parts of Europe (e.g. Poland, the Danube Delta).

7. Recruitment studies. Need to determine age of first breeding in many areas, and to study variations in recruitment rates.

8. Population regulation. Investigations of density-dependent regulation and carrying-capacity effects are needed.

9. Genetic analysis. To re-define the current range of the two sub-species in Europe, especially in areas where the birds are of unknown or mixed status (for example in some parts of Great Britain and France), and to study the genetic composition of 'isolated' groups, for example of Cormorants in Sardinia.

The Group notes the need for a regular synthesis and up-dating of data on Cormorants at an international level.

The Group is keen to encourage continued participation from all countries currently involved in its activities, and would very much welcome more contact with people from the countries not represented to date. Also welcome would be more direct contact with fishery scientists and others who, so far, have had rather little involvement with the Group.

Key recommendations identified at the Gdansk meeting were as follows:

1. That governments and non-governmental organisations provide adequate resources to address the priority research needs identified above and, in particular, support relevant studies in areas where data are most lacking, for example, in central and eastern parts of Europe: the Baltic States, Poland, Ukraine, Czech and Slovak Republics, Hungary, Rumania, Yugoslavia, Bulgaria and members of the Commonwealth of Independent States etc.

2. That consideration be given to the production of a European-wide management plan for Cormorants. Given sufficient resources, the Group notes that its members could coordinate the production of such a strategy, and realises that full cooperation with fishery and bird conservation organisations will be essential. In the meantime, every effort must be made to ensure that certain general principles are common to all country-specific management plans.

3. That, to allow geographical and time-series monitoring, common standards of approach, methodology, data collection and handling be adopted by all those conducting research into Cormorants.

4. That the type of damage (economic, ecological and behavioural) apparent at particular fisheries always be clearly distinguished and, where possible, scientifically quantified.

5. That actions against Cormorants, both lethal and non-lethal, be appropriately designed and coordinated (regionally, nationally and internationally) with respect to the scale of the problem. The Group would welcome the opportunity to comment on proposed Cormorant management before any actions are taken.

6. That this position statement be circulated to relevant governmental and non-governmental organisations.

The Group recognises that it will need to define clearly its principal aims and role over the next few years, and it may be desirable to enlist further expertise and expand its activities. The Group may soon affiliate with the International Waterfowl and Wetlands Research Bureau (IWRB) thus providing a world-wide forum for those interested in cormorant species.

Drafted and produced by J.S. Kirby on behalf of the Cormorant Research Group.

APPENDIX IV

The 1992 NRA Position Statement

- The NRA recognises that in some locations there is considerable concern by anglers that cormorants or sawbill ducks may be adversely affecting fish stocks either strictly through predation or indirectly by affecting fish behaviour. The NRA understands the anglers' concerns.

- The NRA has a duty to both maintain, improve and develop fisheries and to further conservation.

- The NRA has no legal powers to issue licencees to control cormorant or sawbill-related predation. Any enquiries on this issue will be forwarded to MAFF or WOAD as appropriate.

- Unless serious damage to specific fisheries is proved and every effort to deter cormorants or sawbills has failed, the NRA cannot support shooting as a control measure.

- The NRA will continue to liaise closely with MAFF, English Nature, WOAD and the Countryside Council for Wales with regard to assessing the impact of cormorant and sawbill predation, providing relevant information as appropriate.

- The NRA is actively addressing the issue through its research and development programme. This research will take time to reach considered conclusions.

- In the meantime, the NRA will continue to monitor the situation.