Report of the EIFAC working party on prevention and control of bird predation in aquaculture and fisheries operations

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PREPARATION OF THIS REPORT

This report was prepared on the basis of the European Inland Fisheries Advisory Commission (EIFAC) Working Party on Bird Predation which was organized by Ir. C.M. Bungenberge de Jong in response to a recommendation of the Twelfth Session of EIFAC (Budapest, Hungary, 31 May to 5 June 1982). It is based on responses to a series of questionnaires circulated among interested institutions in EIFAC member countries. The publication contains the most up-to-date summary of the present impact of birds on culture and capture fisheries in Europe.

The valuable collaboration of the EIFAC National Correspondents, the Secretary of EIFAC and the members of the Working Party is gratefully acknowledged. I also want to express many thanks to all who have contributed with their kind collaboration in EIFAC activities.

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ABSTRACT

With the appearance of the final Report, the Working Party has terminated its mandate, accepted at the Twelfth Session of the European Inland Fisheries Advisory Commission (EIFAC) (Budapest 1982).

As a result of this investigation it is apparent that in most regions damage caused by piscivorous birds in open waters is mainly of local interest and generally not considered to be of great economic importance. This opinion, however, is no longer shared by those countries which recently have been confronted with large numbers of migrating cormorants. Due to total protection, cormorant populations in Europe have multiplied and now cause increasing problems in open waters.

In trout culture, birds feeding on fish in ponds and raceways cause serious losses, damaged fish which escape capture may contribute to the spread of diseases and parasites. However the intensive, compact pond and raceway systems characteristic of the trout industry are more easily protected than the large, extensive ponds used for many warm-water species.

Among the different types of aquaculture the pond fish are most exposed to bird problems which are difficult to solve economically in view of the large areas involved. Since piscivorous birds in most countries are protected, their populations have increased considerably and in several regions have reached a level at which many pond farms are faced with heavy economic losses. Some pond farms have been totally ruined as a consequence of predation by cormorants and no longer exist.

It is to be hoped that this survey will contribute to a better understanding of the role of bird predation in aquaculture and fisheries operations.

CONTENTS

I WORKING PARTY: ORIGIN, OBJECTIVES AND ACTIVITIES

1. INTRODUCTION

At the Twelfth Session of EIFAC, Budapest, 1982, the delegation of the Netherlands called attention to the fact that fish culture was endangered and near to bankruptcy at the Lelystad Fish Farm (218 ha), due to predation of the rapidly increasing number of cormorants (Phalacrocorax carbo sinensis).

Other regions, for example, pond farms in the Camargue (France), in Bavaria, Schleswig-Holstein and Yugoslavia, heavy losses had also been reported due to predation by cormorants.

As a consequence of the strict protection of this species in the EIFAC region it was suspected that the cormorant populations will increase considerably in the near future and may become a considerable problem for a greater number of fish farms.

The problem of bird predation was of notable interest to many delegations. It was, therefore, recommended that more information be gathered on the whole problem of the impact of birds on aquaculture and fisheries operations.

2. OBJECTIVES

In view of the common interest in this item, the Twelfth Session of EIFAC decided that a Working Party on this subject should be established with the following objectives:

(a) gather information, by means of a questionnaire, on the direct and indirect economical impact of bird predation both in different types of aquacultural enterprises, as well as in open-water fisheries;

(b) prepare a document based on literature and experimental data concerning bird damage in:

- pond fish culture
- trout culture
- open waters

Taking into account related aspects of fish diseases.

It was furthermore decided that the above-mentioned documents (the replies to the questionnaire and the working group document, respectively) will be combined by the Secretariat to be handed over to the Director-General of FAO for further appropriate action.

This report therefore forms part of the remit of the EIFAC Working Party on Prevention and Control of Bird Predation in Aquaculture and Fisheries Operations. Its primary purpose is to review the literature on bird predation, although it also considers the broader aspects of bird/aquatic ecosystem interactions, particularly as they affect fish populations (e.g., disease transmission, trophic state, etc.). It is thus intended to compliment the summary reports on the status of the problems experienced by EIFAC member states prepared from questionnaires.

The report sets out to determine the avian species involved, and to assess the economic losses incurred in open-water fisheries, pond fish farms and trout farms. It also examines the effectiveness of various methods of control. The report draws heavily upon published data from within EIFAC member states, but also includes information from outwith this area, particularly on control methods.

3. WORKING PARTY

The following were nominated members of the Working Party on Prevention and Control of Bird Predation in Aquaculture and Fisheries Operations:

C.M. Bungenberg de Jong (the Netherlands)	-	pond fish culture (Convenor)
J. From (Denmark)	-	trout culture
L. Marion (France)	-	open waters
K. Molnar (Hungary)	-	related aspects of fish diseases

At the Thirteenth Session of EIFAC in Aarhus (Denmark) the Working Party was extended by the addition of Dr M. Beveridge, University of Stirling (UK), who kindly offered to review the literature on this subject.

The Convenor acted at the same time as Secretary of the Working Party and was in touch with the EIFAC National Correspondents, EIFAC Officers, the Secretary of EIFAC and many others.

As no funds were available, contacts between the members of the Working Party were mainly by correspondence. The Convenor has visited France and the United Kingdom in order to discuss certain aspects with the members in these countries.

The activities of the Working Party during the intersessional periods were reported at the Thirteenth Session of EIFAC, Aahus (Denmark) (document EIFAC/XIII/84/13) and at the Fourteenth Session of EIFAC, Bordeaux (France) (document EIFAC/XIV/86/5). The draft report was circulated to the member countries of EIFAC for comment and modification. Replies received have been incorporated into this document.

4. QUESTIONNAIRE

A questionnaire on the economical impact of bird predation provided a good opportunity to gather more information on the bird problem as a whole. Some particular fields of interest, for instance, “predation” or “fish diseases” were selected within each item.

The format of the questionnaire was aimed at eliciting descriptive answers. In this way it was expected that more useful information could be gathered than by a simple “yes” or “no” format. It was not thought feasible to send individual inquiry forms to the thousands of fish farms in the EIFAC region so the questionnaire was sent to the EIFAC National Correspondents, who were well placed most probably to collect adequate information concerning the situation in their countries.

The first draft was prepared in corperation with the Chairman of Sub-Commission II. The topics pond fish culture, trout culture and open waters were drafted by C.M. Bungenberg de Jong, J. From and L. Marion, respectively. The questionnaire, which was sent by the EIFAC Secretariat to the EIFAC National Correspondents is included as Annex 2 to this report.

The Working Party received replies to the questionnaire from the following 18 countries: Austria, Belgium, Cyprus, Czechoslovakia, Denmark, Finland, France, Germany (Federal Republic), Hungary, Ireland, Israel, Italy, the Netherlands, Norway, Poland, Romania, Switzerland and the United Kingdom.

5. LITERATURE REVIEW

Besides the questionnaire, the Working Party also prepared a literature review for which we are greatly indebted to Dr M. Beveridge, whose efforts have resulted in a comprehensive document entitled: "M.C.M. Beveridge, Problems caused by birds at inland waters and freshwater fish farms. A literature review."

II REVIEW OF REPLIES OF QUESTIONNAIRE - PART A. POND FISH CULTURE

C.M. Bungenberg de Jong - Organization for Improvement of Inland Fisheries (Nieuwegein, the Netherlands)

1. GENERAL INFORMATION

1.1 Total area of Fishponds

Estimate of the total area of fishponds (hectares) and the total production (tons) for most countries is given in Table 1. The information obtained from Italy relates to a few locations only as data on the total area of fishponds are lacking. In the case of the United Kingdom, the area of fishponds as estimated from the total production is probably limited to between 100 and 200 ha.

1.2 Production (fish species)

The most important fish species reared in Europe is the common carp (Cyprinus carpio), but the following cyprinid species are also raised: silver carp (Hypophthalmichthys molitrix), bighead carp (Aristichthys nobilis), grass carp (Ctenopharyngodon idella), tench (Tinca tinca), roach (Rutilus rutilis) and some other species from lesser importance.

The east Asian herbivorous fish species are mainly raised in countries with favourable climatic conditions (Hungary, Israel, Romania) whilst in west European countries tench and roach are produced often in polyculture with carp. The bulk of the production consists of cyprinid species and at the most 10% consists of the following predatory species: pike-perch (Stizostedion lucioperca), pike (Esox lucius), wels (Silurus glanis), perch (Perca fluviatilis) and some other species. In Israel, Tilapia spp. and mullets are produced, as well as common carp, silver carp and grass carp.

In most European countries the production level is not high (200–500 kg/ha), but in Hungary (1 400 kg/ha) and in Israel (4 000 kg/ha) higher yields are obtained as a consequence of intensive feeding. Here birds find much higher densities of fish in open waters.

1.3 Number of Pond Farms

Accurate assessment of the number of pond farms is difficult due to the great number of small ponds which are maintained as a side line to some other activity. Austria mentions 30 pond farms of more than 20 ha (a number of them of more than 100 ha) and a great number of small farms with an area of 0.6–10 ha.

Czechoslovakia states that, from the total pond area of 52 000 ha, there are 42 000 ha in the hands of the State Fishery Concern: grouped into 16 State Fish Farms each with 1 500–1 700 ha of ponds. France mentions the total number of ponds to be 5 000.

2. BIRD PROBLEMS

The following answers were received to the question of whether or not there was a local waterbird problem serious enough to hamper fish production. Austria, Belgium, Federal Republic of Germany, Hungary, Israel, Italy and the Netherlands report serious waterbird problems hampering fish production. Czechoslovakia, France, Poland and Romania experience such problems on a local scale. United Kingdom reports some problems with predation by birds. The following problems are encountered in order of importance (see Table 1):

(a) predation - not only causes losses due to direct predation by piscivorous birds, but also as consequence of severe injury;

(b) interference with artificial feeding - not only direct by consumption of food, but also indirect by the disturbance of the feeding process of fish due to concentrations of aquatic and predatory birds on the feeding places;

(c) spread of fish diseases - transport of infectious fish diseases to ponds, pond farms, which were free of fish diseases before. Furthermore, a number of aquatic birds function as host in the life cycle of some parasites, and

(d) disturbance during wintering - when the ponds do not freeze in winter, as in most of western Europe, severe problems can be caused by aquatic birds during wintering.

3. PREDATION

A complete list of all piscivorous birds has been received from a number of countries. In the following we will restrict ourselves to those species which are (locally) common and play an important quantitative role in bird predation. Consequently only a restricted number of bird species is listed for the different countries of the EIFAC region (Table 2).

Some species listed as major predators in some countries are absent or very rare in others. Most instructive in this respect is the situation in Romania, especially in the Danube Delta where all the categories of piscivorous birds mentioned are present. In Romania the order of importance of the different predator categories and separate bird species is as follows:

	Category		Species
(a)	Pelicans	1.	White pelican (*Pelecanus onocrotalus*)
		2.	Dalmatian pelican (*Pelecanus crispus*)
(b)	Cormorants	3.	Great cormorant (*Phalacrocorax carbo s.*)
		4.	Pygmy cormorant (*Phalacrocorax pygmeus*)
(c)	Herons	5.	Grey heron (*Ardea cinerea*) and other heron species

Table 1

Characteristics of pond farms in Europe and the degree to which they experience bird-related problems

Country	Total area of fishponds in ha	Production in tons	Number of pond farms	Serious waterbird problem, hampering fish production	Existing bird problems			
					Predation	Interference artificial feeding	Disturbance during wintering	Spread of fish diseases
Austria	2 600	1 100	>30	yes	+	-	-	-
Belgium	2 500	600	±10	yes	+	+	+	+
Czechoslovakia	52 000	15 000	>16	local	+	+	+	+
France	40 000	7 500	-	local	+	-	-	-
Germany (FR)	14 300	10 000	8 980	yes	+	+	+	+
Hungary	21 700	30 300	±110	yes	+	+	+	+
Israel	3 000	12 000	±70	yes	+	+	-	+
Italy	-	-	-	yes	+	-	-	+
The Netherlands	300	120	3	yes	+	+	+	-
Poland	40 000	10 000	-	local	+	+	-	-
Romania	118 350	37 100	242	local	+	+	+	+
United Kingdom	-	50	4	some	+	-	-	-

Table 2

Predation by fish-eating birds, numbers refer to order of importance in each country

Country	Grey heron	Gull sp. (terns)	Great crested Grebe	Cormorant	Pelican sp.	Other species
United Kingdom	1	-	-	-	-	
Belgium	1	2	-	-	-	
Czechoslovakia	1	2	-	-	-	
Italy	1	2	-	-	-	
Austria	1	4	3	2	-	(terns, white stork)
Poland	1	3	2	(4)	-	
Germany (FR)	1	2	(4)	3	-	
France	1	3	-	2	-	
Israel	2	3	-	-	1	(white stork)
Hungary	3	2	-	1	-	(spoon bill)
The Netherlands	3	-	2	1	-	(diving ducks)
Romania	3	(4)	(5)	2	1	

Category		Species
(d) Gulls	6.	Black-headed gull (<u>Larus ridibundus</u>) and other gull and tern species
(e) Grebes	7.	Great crested Grebe (<u>Prodiceps cristatus</u>) and other grebe species

Other countries with experience of pelicans and cormorants are in complete agreement with the Romanian conception that these two categories are the most feared predators in pond fish farming.

In the EIFAC region generally pelicans are of only local importance as they are only known from Romania and Israel. These birds are also considered as the major fish-eating bird in Israel where they are present from October to March. Directly after pelicans, cormorants are undoubtly the most harmful predators in pond fish farming. In both Hungary and the Netherlands the great cormorant is ranked as first among the fish-eating birds in pond farming.

Furthermore, the great expansion of the cormorant populations in Denmark and the Netherlands, where they are totally protected, migrating cormorants cause more and more problems in Austria, France (fish farms Camargue), Germany (fish farms Schleswig-Holstein) and Switzerland.

Cormorants cause considerable incidental damage to fish by pursuing the shoals under water causing a panic reaction. Fish endangered in this way will hide in the vegetation on the banks or cluster in harvesting sumps for a long time. When disturbance by cormorants is continuous, the stressed fish will not leave their hiding places, do not eat and as a consequence will finally die of starvation, or disease. It is a remarkable fact that fishponds used for raising two-year old carp are frequently practically without fish when fished in the autumn due to comorant attacks. It apears that the fish population is totally fished out by cormornts, but in fact it is the stress effect which has the major impact on the fish population. Because this cormorant predation often means total bankrupt, especially in fish farms raising stocking material.

Herons are mentioned as the most important predator category in pond fish farming in Austria, Belgium, Czechoslovakia, France, Germany, Israel, Italy, Poland, Romania and the United Kingdom. Gulls are considered more harmful in Hungarian fish farms than herons, but less so than cormorants, whereas grebes cause more damage than herons, but less than cormorants in the Netherlands.

Gulls (terns) are generally ranked after herons in Belgium, Czechoslovakia, France, Germany, Israel, Italy, Romania. In Austria and Poland the great crested grebe causes more damage in pond fish farming than do gulls (terns). The damage caused by fish-eating birds differs according to species.

<u>Herons</u>

Herons operating along the banks are restricted to the shoreline or to wading in shallow water. They have a limited radius of action and eat fish of up to 250 g. Pond farms mainly raising 300–1 200 g carp for consumption in ponds with more than 100 cm water depth will have restriced losses due to herons. Otherwise, herons can cause considerable damage in ponds with an insufficient water level or ponds loosing water towards the end of the growing season, especially in those fish farms raising stocking material.

<u>Gulls (terns)</u>

The black-headed gull (Larus ridibundus) is the most common gull species on fish farms. They are observed particularly during the growing season on shallow fingerling ponds. Black-headed gulls, which occur often in very great flocks, can involve high losses of fingerlings especially during the autumn harvesting. In Hungary, herring gulls (Larus argentatus) visit the harvesting sumps in October in very high numbers. During a short period of time they can cause higher losses by direct predation and injury than black-headed gulls during the whole season.

Piscivorous birds pursuing fish under water

The most efficient fish-eating birds belong to this group: grebes, mergansers, cormorants and pelicans have an unlimited radius of action covering the whole fish ponds. The limiting factor is mainly the size of prey: grebes take fish of up to 120 g, cormorants up to 600 g and pelicans catch fishes up to 1 kg. Unlike herons and gulls, these typical aquatic birds rarely cause problems at the time of harvesting when the ponds are emptied.

Besides such typical fish-eating ducks as mergansers some diving ducks also belong to this group. Common species, such as the tufted duck (Aythya fuligula) and the pochard (Aythya ferina) have proved dangerous to smaller fish in wintering ponds. In summertime fish will normally swim rapidly enough to escape these non-specific fish predators. But in winter, when the fishes move only slowly, diving ducks can seriously disturb one-year old carps in the wintering ponds. When the fishes are not small enough to be eaten by the ducks, they injure up to 80% of the fish population, which die later.

4. INTERFERENCE WITH ARTIFICIAL FEEDING

Three main problems arise where artificial feeding is practised. Firstly, there is direct competition where the feeds intended for fish are eaten by birds. Secondly, fish may be disturbed by birds and receive less food than normal and finally there is the concentration of predatory birds on the feeding places, resulting in a higher predation and an increase in the number of injuries. This problem is not restricted to conventional methods of feeding, but may be even worse when automatic feeders are used.

In order of importance coots (Fulica atra), ducks and local swans were mentioned. Of the ducks, the mallard (Anas plathyrhynchus) and the diving ducks (Aythya ferina, Aythia fuligula) are considered of importance in this respect. Grain, as well as pellets are eaten by these birds. Birds quickly learn to operate automatic feeders, with the consequence that pellets fall into the water and are lost by disintegration. The financial losses caused are substantial and in Hungarian pond farms are comparable with losses caused by predation.

5. DISEASES

See Part D of Review of Replies to Questionnaire.

6. MEASURES

From the replies to the questionnaire it is apparent that all possible attempts have been made to prevent bird damage in pond farms. Unfortunately, however, most methods have proved to be ineffective (Table 3).

Table 3

Non-lethal protection methods

Country	Physical Barriers: Complete enclosure (screen/nets)	Physical Barriers: Overhead lines or wires	Physical Barriers: Perimeter fencing or wires	Frightening Devices: Acoustic Deterrents: Automatic exploders	Frightening Devices: Acoustic Deterrents: Cracker shells	Frightening Devices: Visual deterrents	Protection of feeding places (nets/wires)
Austria	+	+		N	N	N	
Belgium	+	+		N	N	N	+
Czechoslovakia				t	t		+
France		+		t			
Germany (Fed. Rep.)							
Baden Württemberg	+	+	+	t	t	t	
Bayern	+	t		N		t	+
Niedersachsen		+	N	t		N	
Nordrhein Westfalen			N	N		N	
Reg. Bez. Stuttgart	+	+	N	N	N	N	
Schleswig Holstein			N		t		
Hungary					N		
Israel		+		N	N	N	
Italy	+	t					
The Netherlands	+	t		t	N	N	+
Poland							+
Romania				t	N	N	
United Kingdom	+	+		N	N		

+ = effective; t = temporary effects; N = no results

Two non-lethal methods are commonly used to prevent bird damage:

(a) complete or partial exclusion using physical barriers, and
(b) various frightening devices (acoustic and visual deterents).

(a) Physical barriers

(i) Complete enclosure. In general enclosing ponds to exclude all fish-eating birds require 3–5 cm mesh netting secured to frames or supported by overhead wires. This method is successfully employed in the Netherlands to prevent winter damage to carp fingerlings (± 25 g) by diving ducks. In contrast with trout farms this effective method can only be used on a small scale in pond farms because of the high costs.

(ii) Lines or overhead wires. Ponds can be covered with overhead wires or monofilament lines suspended horizontally in parallel dug in one axis or a crossing on two axes. Spacing between the wires or lines should be based on the type of birds causing damage.

In Israel, against pelicans, strings are stretched across ponds at 30–40 m intervals and around the circumference of pond embankments (0.5 m high). If the strings are properly installed they are very cheap and effective. Experiments have been made in the Netherlands on a large scale with overhead lines crossing in two axes of 20 × 20 m on larger ponds (10 ha) to prevent damage by cormorants. In the first year this method proved to be successful, but in subsequent years the cormorants changed their behaviour and learned to pass through patterns as small as 5 × 5 m. In the USA it was found that 120 cm spacing was effective in deterring gulls. To exclude mergansers 60 cm spacing is necessary and a minimum of 30 cm is required for herons and terns.

(iii) Perimeter fencing or wire. Perimeter fencing or wire around ponds provided some protection and is most effective for herons. But after some time also herons learn to avoid these obstacles.

(b) Frightening devices

Generally the use of frightening devices (automatic exploders, bird control shells, alarm or distress calls and lights) is not effective, because most birds rapidly become accustomed to them.

The replies to the questionnaire indicate that automatic exploders can be used under certain circumstances. For example, this method is often used with success some days before emptying a fishpond to prevent damage by herons, and in the Netherlands it was found that it is possible to deter mergansers on 10 ha-ponds by automatic exploders. Acoustic methods can be more effective if reinforced by shooting. In the replies, the use of distress calls is not mentioned and all respondents agree that the use of visual deterents has no value.

In several countries, interference with artificial feeding can be prevented. In Czechoslovakia, for instance, protection against birds is carried out by installation of wire nets in the water column (25–30 cm under water level) above the feeding places. Feed drops through the wire net and can be taken by fish but not by birds.

7. LEGAL POSITION

See Part B Legal Position and Part C Bird Predator Populations (Legal Position).

8. INDEMNIFICATION

No provision for indemnification for damage caused by protected birds exists in countries responding to the questionnaire. Indemnifications have been granted in the case of severe damage by cormorants only in Schleswig-Holstein (Federal Republic of Germany).

9. ECONOMICAL IMPACT

The replies to the questionnaire gave an evaluation of the economic losses caused by bird produced damage by country as follows:

Austria

Losses by birds due to predation have increased considerably in the last few years and in places have reached an unacceptable level. In several ponds containing one-year old coregonids damage caused by herons and grebes was estimated at 20–30% of the yearly production. Damage to one-year old carps was estimated to be 20% and to two-year old carps more than 10%.

Belgium

Damage caused by piscivorous birds differs from fish farm to fish farm. Predation by herons, the main predator, caused a loss of production of between 10% and 60%.

Czechoslovakia

Birds, especially herons, hamper fish production locally. Rough estimates indicate that birds decrease the production of carp by 10% in these localities. Carp fry to yearlings are primarily affected by birds.

France

The specialists of the National Institute of Agricultural Research and the Working Party on Piscivorous Birds differ from fishfarmers in considering bird predation of slight importance. The only exception is the great cormorant which can cause local problems in the Camargue and in Brenne.

In the Camargue, predation by cormorants is a “new and unexpected” problem, due to the explosive increase of the cormorant populations in the Netherlands and Denmark. Formerly cormorants were seldom seen in the Camargue, but today more than 6 000 cormorants are present from October to March. Confronted with this alarming situation the Government has ordered research to assess the damage caused by cormorants. Research at Tour du Valet has been carried out on five pond farms in order to estimate the damage caused by cormorants over the four years from September 1981 to March 1984. It was found that losses to these pond farms were 47 000 kg with an economic value of F 846 000 per year. As a consequence production costs have risen to an unprofitable level, several fishfarmers were forced to go out of business, and the total area of fishponds in the Camargue was reduced from 1 020 ha in 1981/82 to 500 ha in 1983/84. The cormorant problem is international and countries with rapidly increasing breeding populations such as Denmark and the Netherlands should take measures to control these populations. To do this the countries of the European Community should consult to fix the number of cormorant breeding pairs that are desirable within each country.

Germany, Federal Republic of

Bayern: Four fish farms with a total area of 265 ha of ponds have suffered damage of at least DM 125 000 per year. This is mainly caused by predation by herons, grebes and gulls, and interference with artificial feeding by coots, ducks and swans. One fish farm reported 30–50 herons on 30 ha of fishponds; another fishfarmer reported 120 herons on 75 ha of fishponds (1.6 heron/ha). Perhaps even more damage is caused by the great crested grebe, especially in fish farms raising stocking material. Most endangered are ponds with one-year old tench or one to two-year old carp which suffer losses of up to 80%. One fishfarmer was forced to stop raising small fishes and switched over to the less profitable production of carp for consumption. The feeding places of another farm with 70 ha of ponds were frequented by 500 ducks (mainy tufted duck), 400 coots and 15–20 swans, which disturb the fishes and cause high losses of food (grain, pellets).

The great cormorant has become established in Bavaria near the well-known fish farm "Birkenhof" (200 ha). Here a breeding colony of 70 pairs has been set up in the "Speichersee" at Ismaning near Munich. In a short time the visiting cormorants wrecked the farm: wintering ponds stocked with one and two-year old carp were practically totally fished out and the losses of two to three-year old carp of the order of 50–80%. As carps of up to 550 g are vulnerable to cormorant predation and larger carps up to about 700 gr can be severely wounded by cormorants failing to swallow them, the only alternative is to stock ponds with carps greater than this weight. Under these circumstances fish culture is no longer profitable.

Niedersachsen: In 1977 a questionnaire was distributed in the area of Hannover to gather more information on the economic impact of bird predation. Replies were received from 20 pond farms. Damage to these farms amounted to DM 225 000 (herons: DM 177 000, other birds DM 48 000).

Nordrhein-Westfalen: Three carp farms with a combined area of 200 ha sustain damage of at least DM 75 000/year, mainly caused by herons.

Schleswig-Holstein: Damage caused by herons is estimated on 10% of the yearly production (total area of carp farms 1 700 ha with a production of 340 t two and more year old carp plus 1.6 million one-year old carp. Local heavy losses of up to 80% have been reported due to cormorants which have caused financial losses amounting to DM 10 000 to DM 30 000 per fish farm.

Hungary

A special survey was carried out in four large fish farms with a combined area of 7 385 ha (34% of the total pond area in Hungary) in 1984 to gather more information on bird problems. Results of this survey of fish-eating bird species were as follows (in order of importance):

(a) cormorant (Phalacrocorax carbo)
(b) herring gull (Larus argentatus)
(c) black-headed gull (Larus ridibundus)
(d) grey heron (Ardea cinerea)
(e) spoonbill (Platalea leucorodia)
(f) purple heron (Ardea purpurea)
(g) little egret (Egretta garzetta)
(h) great white egret (Egretta alba)

Cormorants cause damage over the whole growing season of the fish. From March to July they visit ponds stocked with one or two-year old fish. From late summer they also appear on fingerling ponds. Losses due to predation by cormorants are about 200 t/year on the four large fish farms and approximately 300 t in the whole country (Ft 12 million). Damage due to black-headed gulls can also be observed during the whole breeding season in shallow fingerling ponds. These birds can involve great losses of fingerlings especially during the autumn harvesting.

Herring gulls and some other migrant gull species visit the harvesting sumps in October in a higher number. Within a short period of time they can cause higher losses both by direct predation and by injury than can black-headed gulls during the whole season.

On the four large farms losses due to all gull species are 100 t/year. It means 300 t at country level (approximately Ft 16.5 million in value).

The feeding habits of grey herons and purple herons in pond farms are rather similar to those of cormorants, but losses are much lower. In spring they visit ponds stocked with one-year old fish. In summer, as fish fry grow, they also can be found on fingerling ponds. In the fish farms investigated, the damage due to these bird species is about 30 t/year, so at a country level 90 t (approximately Ft 3.6 million).

Spoonbills are important only in a few areas. During summer they can eat a large number of valuable common carp and herbivorous fish fry. On the Hortobágy fish farm this means 1.5–2 million fry/year. At country level a value of Ft 1.5 million can be estimated.

The populations of little egret and great white egret are growing very quickly in some areas of the country due to protection. It seems possible that these species will cause serious losses on fingerling ponds in the future.

Only two species, mallard (Anas platyrchynchos) and coot (Fulica atra) are important in that they interfere with artificial feeding by eating both cereal grains and pelleted feeds as well.

At the largest Hungarian fish farm, Hortobágy (4 100 ha), feed losses due to mallards are estimated at 8 t/day, and due to coots at 1.5 t/day. On the Szeged fish farm (1 839 ha) 220 t/year are taken by mallards and 45 t/year by coots. At country level 4 000 t of feed intake by birds can be estimated (approximately Ft 24 million).

Summarizing the above data, the economical losses and extra costs to the Hungrian fishfarming sector can be roughly estimated as follows:

predation:	Ft 33.6 million	= US$ 672 000	(based on producers prices of different species and year-classes)
feeds:	Ft 24 million	= US$ 480 000	(purchase price)

Israel

The main impacts of birds on aquaculture in Israel are through predation also interference with artificial feeding and disturbance during harvesting.

The following fish-eating birds are of special importance because of their economical impact:

Pelicans are present from October to March. Some individuals stay all winter, but most migrate to Africa during the months of January and February. They feed mainly on tilapia and carp winter stocks consisting of fish ready for marketing. They also raid fish ponds during harvesting. They take fish of up to 1 kg and effective predation takes place in fish ponds of 2 m depth (or less).

Storks and herons: (white, purple and grey), some herons remain all year round, whereas others migrate to Israel during October–December and again during March–May. They feed mainly on fish weighing less than 150 g. The main damage is in tilapia fry wintering ponds when the temperature drops to less than 12°C. Herons also predate on fish while they gather under the demand feeders or when they are sick.

Sea gulls are present all year round. They mainly disturb fish during the harvest by pecking on them. In addition to the wounds they cause, the disturbance of the fish considerably increases the turbidity of the water, which in turn, will eventually cause the death of many fish. Sea gulls also peck on sick fingerlings.

Interference with artificial feeding is mainly caused by herons and sea gulls while fish are gathered under automatic or demand feeders. The bird interference is independent of food quality. All together the estimated damage caused by birds on pond farms in Israel is approximately US$ 500 000 per year.

The Netherlands

Dutch pondfarming has problems with grebes, diving ducks and herons, which cause extra losses due to predation of 15–20% in one to two-year old carp and 5–10% in two to three-year old carp. These problems are, however, relatively slight as compared with those caused by cormorants. As an example of the effects of cormorant predations we cite the history of the fish farm (170 ha fishponds) near Lelystad in the eastern Flevoland polder, which have been successfully operated since 1963. After reclamation of the neighbouring southern Flevoland polder in 1978, a cormorant colony settled in the newly established State Nature Reserve “Oostvaardersplassen” (5 000 ha), approximately 13 km south-southwest of the fish farm. The development of this colony was explosive: from 1978 onwards estimated numbers of breeding pairs were 175, 790, 1 100, 2 000, 2 500, 3 900, 4 600 up to 5 100 in 1985. In the following years the colony was maintained at this level and a further increase in population took place in a daughter colony at a distance of 10 km south-southwest of the main colony.

Although plenty of food is available for the cormorants in Lake IJsselmeer with 185 000 ha of rich fishing grounds, cormorants visited the fish farm in increasing numbers from 1979 onwards. In 1979 regular groups of cormorants were seen fishing on the fishponds. By 1980 some ten cormorants visited the fish farm every day. In 1981 this number increased to several hundreds (300–600 yearly) with flocks of even more than 3 000 cormorants per day (April 1981).

Higher losses were estimated in carp culture in 1979, but in following years this enterprise was completely ruined due to cormorant predation, as can be seen from the following data:

Year	Class	Area ha	Stocked		Harvested		Losses %		Prod. kg/ha
			numbers	kg	numbers	kg	pond	control	
1980	$C_{1–2}$	53	137 887	10 456	32 182	8 137	77	10	-44
	$C_{2–3}$	63	42 517	18 323	27 515	35 457	35	0	272
1981	$C_{2–3}$	63	24 183	10 903	6 870	10 907	72	2.4	0

In 1980 severe losses (35%) had already been registered in the production of three-year old carp, whilst the production of two-year old carp was a complete disaster: a greater weight of one-year old carps was stocked than was harvested as two-year old carps.

In view of this situation, the production of two-year old carp was abandoned and it was decided to grow only three-year old carp in 1981. Although the six ponds (area 63 ha) were stocked with carp of a mean weight of 450 g, the losses of two to three-year old carp increased in 1981 to 70% and production was zero.

There can be no doubt that these losses were inflicted during massive cormorant visits. Carp of the same origin were stocked at the same time in small experimental ponds (0.2 ha) as a control. As can be seen from the control column of the above table, losses in the experimental ponds which were never visited by cormorants were low and contradict the popular view that cormorants will only eat sick fishes.

During subsequent years a lot of trouble and money were investigated in the development of methods to prevent cormorant damage. Although the use of overhead lines and the application of ultrasonic sounds seemed promising at first, it was found that these methods were less successful after continued use, as the cormorants learned to avoid these obstacles. Near to bankruptcy, finally the greater part of the ponds was taken out of production and a flourishing fish farm was abandoned due to cormorant predation.

Poland

Opinions on whether bird problems do exist, vary from farmer to farmer. Predation by herons (Ardea cinerea), grebes (Podiceps cristatus), terns (Sterna sp.) and cormorants (Phalacrocorax carbo) (listed in order of importance) is considered serious with regard to fry and fingerlings. Ornithologists, however, claim that due to the rather small populations of piscivorous birds in Poland, predation on cultured fish will be in general negligible.

Interference with artificial feeding has been observed on several fish farms. A study of this problem in four fish farms, including the largest fish farm in Poland, the State Fishery Enterprise in Milicz, revealed that the dominant species feeding on fish food are: pochard (Aythya ferina), tufted duck (Aythya fuligula), mallard (Anas platyrhynchos) and baldcoot (Fulica atra). Population densities of these species estimated in four fish farms, totalling 4 000 ha of fishponds, varies until mid-July from 2.9 to 6.8 specimens/ha. After mid-July the populations increased from 5.3 to 15.2 specimens/ha. During the period when fish are feeding, these bird species consumed 2.0–7.4% of the food given to fish.

Romania

There are local serious problems from fish-eating birds. Most affected are: the Danube Delta and the floodplains of the Danube and the Prut, Siret, Mures and Olt rivers. Fish farms and especially rearing stations in these regions are strongly attached by fish-eating birds from March to October. Most vulnerable to predation are ponds of over 5 ha and an average water depth of 1 m. The turbidity of the eater is an element which contributes to the intensification of predation. There are cases where ponds have been totally fished out by predatory birds.

Interference by birds with artificial feeding is also a problem. Coots (Fulica atra), especially, interfere with artificial feeds distributed on special fixed places in the ponds. A great number of coots are attracted to the feeding places, plunging into the water immediately after the feeds are administered to fish. They eat pellets as well as a mixture of grits.

Predatory birds intensely stress pond fish during feeding, especially in shallow ponds. Gulls (Laridae) are very active now and the presence of uneaten feeds can be noted, because of attacks of predatory birds.

Fish-eating birds are also important vectors in the spread of fish diseases and parasites. As sick fish are highly vulnerable to predation, fish-eating birds may prevent the early discovery of diseases.

There are normally no problems with birds during the winter in fish farms. During mild winters however, when the water does not freeze, the great majority of the predatory birds does not leave the breeding and feeding areas. Piscivorous birds do not normally disturb fishes in wintering ponds, but during mild winters cormorants can cause heavy losses.

The damage caused by birds on pond fish farms in Romania is estimated at 20% of the fish production. It means a loss of production of 8 000 t and, in terms of monetary value, some US$ 6 400 000/year.

Other replies

Other replies did not contain estimates of economical impact. However, this does not mean that no bird problem exists. On the contrary practically all fishfarmers struggle in one way or another against birds, but losses are often difficult to distinguish from those arising from other sources.

II REVIEW OF REPLIES OF QUESTIONNAIRE - PART B. TROUT CULTURE

J. From - Danish Trout Culture Research Station (Skaerbaek, Denmark)

1. GENERAL INFORMATION

1.1 Total Area

The figure of 3 ha given for Ireland is open to question as the author knows of only one Irish trout farm whose ponds have an area of 2.2 ha.

1.2 Total Production

The production is mostly of rainbow trout (Salmo gairdneri), but the following species are also raised: sea trout (Salmo trutta trutta), brown trout (Salmo trutta fario), lake trout (Salmo trutta lacustris), Atlantic salmon (Salmo salar), char (Salvelinus alpinus), brook trout (Salvelinus fontinalis), Salvelinus (Cristivomer) namaycush, Coregonus peled (=C. muksun), Coregonus pidschian (kilch) and grayling (Thymallus thymallus).

1.3 Number of Trout Farms

Austria reported 30 big farms and several hundred small ones. Niedersachsen (Federal Republic of Germany) has 45 farms where fish culture is the principal occupation and 240 farms which rear fish as a sideline.

2. BIRD PROBLEMS

Most countries claim to have problems with birds. Normally these consist of predation, but involve spreading of diseases (see Table 4), and to a lesser extent interference with feeding (Belgium, Bayern (Federal Republic of Germany) and stress (Oulu Fish Farm (Finland)).

3. PROTECTION AGAINST BIRDS

All respondents, except for that of Niedersachsen, reported that nets or threads are the most effective measure. Their effectiveness depends on the distance between them and although no information was given for most countries, the maximum distance between threads allowed in Denmark is 20 cm.

Tripwires were mentioned by Austria, Niedersachsen and the United Kingdom. However, tripwires were judged to have no effect in the first two of these and the United Kingdom just mention that they are used.

Optical and acoustical signals were mentioned by Austria, Denmark, Inari fish farm (Finland), Oulu, Niedersachsen, Nordwürttemberg (Federal Republic of Germany), the Netherlands, Poland and the United Kingdom. Poland mentioned that shooting is sometimes used. Apart from Poland all reported that these measures are ineffective.

The Institute of Parasitology, Abo (Finland) mentions the use of scare crows and Nordrhein-Westfalen (Federal Republic of Germany) mentions dogs. Niedersachsen, which claims that threads have only limited effect, states that shooting of some grey herons (Ardea cinerea) proved to be very successful. Further, providing special feeding ponds for the birds has proved successful in some areas. Nordwürttemberg and the United Kingdom both advocate steepsided ponds with deep water as a protection against grey heron.

Table 4

Characteristics of trout farms in Europe and the degree to which they experience bird-related problems

Country	Area in ha	No. of trout farms	Product. in tons	Product. t/ha	Bird problems	Protect. against birds	Diseases	Research
Austria	Unknown		2 500		yes	yes	yes, no importance	no
Belgium	500	15	400	0.8	yes	yes		yes
Cyprus	0.3	5	55		no			no
Czechoslovakia					small	yes	yes	no
Denmark	400	520	23 000	57.5	yes	yes	yes	yes
Finland								
Inst. of Parasitology, Abo						yes	yes	
Nat. Vet. Inst., Helsinki					yes		yes	
Inari Fish Farm	0.2		9.0	45.0	yes	yes	yes	no
Montta Fish Breeding Station	2.2		19.0	8.6	yes	yes	yes	
Oulu Fish Farm	1.1				yes	yes	yes	no
France		710	20 000		yes	yes	no	yes
Germany (Fed. Rep.)	567	1 930	5 300	9.3	yes	yes	locally	yes
Hungary		3	300		no			yes
Ireland	3.0	19	560	186.7	yes	yes	no evidence	
Israel	Unknown							
Italy					yes			
The Netherlands	6.0	16	200	33.3	yes	yes	yes	no
Poland			2 000		yes	yes	yes	no
Romania	20.2	55	230	11.4	no	no	no	no
Switzerland		60	700–1 000			yes	unknown	yes
United Kingdom	Unknown	450	10 000		yes	yes	probably	yes

It may be concluded that nets and threads are the only measures which give satisfactory protection against birds.

4. PREDATION

All the answers that mention grey heron (Ardea cinerea) put this species as the most important. Further, gulls (Larinae) are important predators, too. The following species were reported by the countries listed:

Grey heron (Ardea cinerea)	Austria Belgium Denmark Cyprus France Ireland Netherlands Switzerland United Kingdom	Federal Republic of Germany: Baden-Württemberg Bayern Niedersachsen Nordrhein-Westfalen Nordwürttemberg
Gulls (Larinae)	Belgium Czechoslovakia Denmark Poland	Finland: Institute of Parasitology, Abo Montta Fish Breeding Federal Republic of Germany: Bayern and Niedersachsen
Black-headed gull (Larus ridibundus)	Austria France Netherlands United Kingdom	Finland: Inari Fish Farm Oulu Fish Farm Federal Republic of Germany: Baden-Württemberg Nordwürttemberg Schleswig-Holstein
Comm gull (Larus canus)	Finland: Inari Fish Farm Oulu Fish Farm	Federal Republic of Germany: Schleswig-Holstein
Herring gull (Larus argentatus)	United Kingdom	Finland: Inari Fish Farm Oulu Fish Farm
Great black-headed gull (Larus marinus)	Finland: Inari Fish Farm	
Lesser black-headed gull (Larus fuscus)	United Kingdom	
Kingfisher (Alcedo atthis)	Austria Belgium Cyprus Denmark France Ireland Poland (few) United Kingdom	Federal Republic of Germany: Baden-Württemberg Niedersachsen Nordrhein-Westfalen Schleswig-Holstein

	(probably)	
Cormorant (Phalacrocorax carbo)	France Ireland United Kingdom	Federal Republic of Germany: Bayern
Great crested grebe (Podiceps cristatus)	Poland	Federal Republic of Germany: Bayern Niedersachsen
Terns (Sterninae) Arctic tern (Sterna paradisaea)	Denmark Finland: Inari Fish Farm	Poland
Common tern (Sterna hirundo)	Federal Republic of Germany: Schleswig-Holstein	
Goosander (Mergus merganser)	Finland: Inari Fish Farm	Federal Republic of Germany: Bayern
Hooded crow (Corvus corone cornix)	Denmark	
Carrion-crow (Corvus corone corone)	Federal Republic of Germany: Nordrhein-Westfalen	
Wild ducks (Anatidae)	Federal Republic of Germany: Bayern	

Answers to the questionnaire gave little indication as to the size of fish subject to predation. The only data available were reported as follows:

Austria	Predation takes place up to 15 cm
Denmark	Up to 500 g
Finland: Inari Fishfarm	Fish up to two years old, but bigger fish are wounded
Federal Republic of Germany:	
Bayern	All fish sizes
Niedersachsen	Grey herons eat fish 10–16 cm
Ireland	Fingerlings (6–30 g) are eaten
The Netherlands	Up to 200 g (marketable size)
Poland	1–100 g fish are eaten
United Kingdom	Grey herons eat fish of 75 g. Cormorant takes fish on less than 1 kg. Black-headed gull, herring gull and great black-headed gull eat fish up to 10 cm

5. DISEASES

See Part D - Fish Diseases

6. LEGAL POSITION

See Part C - Bird Predator Populations (Legal Position)

Austria	All birds are generally protected. Grey heron can be shot in lower Austria in September. In upper Austria gulls are only protected from 15 April to 15 July.
Belgium	Grey heron and kingfisher are protected
Cyprus	All fish-eating birds are protected
Czechoslovakia	All fish-eating birds are protected
Denmark	Grey heron is protected, but can be hunted all year round inside fish farms. Black-headed gull, common gull and herring gull can be hunted from 1 September to 29 February. Other gulls, terns and kingfishers are protected unconditionally. Carrion-crow and hooded-crow are protected, but can be hunted from 1 July to 30 April inside fish farms. No licence is needed to hunt birds on fish farms.
Finland	Black-headed gull and herring gull are not protected. The other birds are protected, but all birds can be shot on fish farms if they cause damage.
Federal Republic of Germany	<u>Baden-Württemberg</u>: Grey heron and kingfishers are protected. Black-headed gull can be shot. <u>Bayern</u>: Grey heron is protected from 16 September to 31 October. <u>Niedersachsen</u>: All birds are protected all year, except for gulls which are protected from 30 April to 16 July and coot which are protected from 15 January to 1 September. Licence can be given to shoot the following birds on fish farms: gulls, grey heron, great crested grebe and coot. <u>Nordrhein-Westfalen</u>: Kingfisher is protected. <u>Nordwürttemberg (Regierungsbezirk Stuttgart)</u>: Grey heron is protected. Black-headed gull is protected from 1 May to 15 July. <u>Schleswig-Holstein</u>: Grey heron is protected, but licence can be given to shoot a maximum of 8 specimens/year within 200 m of the farm. Common tern, kingfisher and osprey are protected. Black-headed gull can be hunted from 16 July to 30 april and common gull can be hunted from 16 August to 30 April.
France	All fish-eating birds are protected.
Ireland	Fish-eating birds are protected, but may be shot under licence if create damage.
Italy	All fish-eating birds are protected.
Poland	All fish-eating birds are protected.

Netherlands	Fish-eating birds are protected, but may be shot under licence if create damage.
Romania	No licences at fish farms can be given.
Switzerland	Grey heron is protected
United Kingdom	Kingfisher is protected. Licence may be given to shoot grey heron, cormorant, and lesser black-headed gull on fish farms, if predation is serious.

7. RESEARCH

See Part C - Research.

8. ECONOMICAL IMPACT

The Netherlands is the only country where partial compensation for damage resulting from bird predation has been obtained from the Government. This was due to a special circumstance when a licence to shoot birds was not granted in time. Estimates of economic impact for some countries are as follows:

Finland	National Veterinary Institute, Helsinki: Two-year old eye flukes have destroyed more than 10% of the fish population in three cases. Oulu Fish Farm: Damage of about Fmk 30 000 (US$ 5 600) was sustained in the summer of 1983.
Federal Republic of Germany	Bayern: DM 30 000/year/farm (US$ 12 500). Niedersachsen: DM 500 000/year (US$ 210 000). Nordwürttemberg: Grey herons eat 118.6 t of the total yearly fish production and catch of 700 t.
Ireland	Losses are estimated at 27.5%.
Netherlands	Losses are estimated at 10–20%.
Poland	Loss for small fish are estimated at up to 20%.
Switzerland	Fishfarmers guess an annual damage of Sw F 500.00–1 000.00 (US$ 250 000–500 000).

II REVIEW OF REPLIES OF QUESTIONNAIRE - PART C: OPEN WATERS

L. Marion - Laboratoire d'Evolution des Systèmes Naturels et Modifiés, Université de Rennes (France)

1. GENERAL INFORMATION

1.1 Total Area of Open waters

Most countries do not indicate the area of each kind of open water. In consequence it is not possible to evaluate the total biomass of fish available to piscivorous birds based on hypothetic densities for the different types of open waters.

The surface area covered by open waters is very different from one country to another. Fish populations and piscivorous bird problems are then also very different.

Table 5

Surface area of inland waters in various countries of Europe

Country	Lakes (ha)	Reservoirs (ha)	Rivers (ha)	Total (ha)
Austria	55 000		80 000	135 000
Belgium			24 000	
Cyprus		1 177		
Czechoslovakia				65 000
Denmark	42 000	1 000	7 000	
Finland				
France				550 000
Germany (Fed.Rep.)				400 000
Hungary				130 000
Ireland	22 126	3 804	168 243	335 000
Israel				
Italy	354 500	50 000	7 782	400 000
Netherlands	70 000	185 000	80 000	335 000
Norway	164 000	500 000	284 000	948 000
Poland				400 000
Romania		8 700	279 000	694 000
Switzerland	130 000		40 000	
United Kingdom				258 000

Catches by sport fishermen are low in the United Kingdom (0.71 kg/year), Belgium (1.67 kg/year), mean in the Netherlands (3 kg/year) and in Switzerland (5 kg/year), high in Norway (7.13 kg/year), very high in France (10 kg/year), Poland (13.33 kg/year) and in Czechoslovakia (15.44 kg/year).

In Europe, there are an estimated 15 million sport fishermen, catch about 6.4 kg/year, that is to say a total of about 100 000 t. This figure seems rather high in comparison with data on predation by birds (for example, the European heron population will consume the equivalent of about 10% of the fish caught by sport fishermen).

2. BIRD PROBLEMS AND PREDATION

Populations of piscivorous birds and characteristics of open waters differ between countries. Consequently, bird problems depend on local situations in each country. Unfortunately, some responses to the questionnaire only list piscivorous birds, and do not give information on problems.

Grey heron (Ardea cinerea): France, Belgium, Hungary, Austria, Federal Republic of Germany (in regulated brooks and small rivers), Switzerland (only on trout in winter in small rivers), experience problems with the species, but predation is not quantified. In France, the problem is largely subjective in that fishermen feel that herons cause considerable damage, but fish specialists of the National Institute of Agricultural Research (INRA) consider that damage is negligible. Ireland, United Kingdom, Norway, Denmark, Finland, Poland, the Netherlands and Cyprus do not mention this species as a problem.

Great cormorant (Phalacrocorax carbo): Problems are experienced with this species in Romania (Danube Delta), and also in fisheries on IJsselmeer and estuaries in the southwest part of the Netherlands where problems especially concern breeding populations in spring and summer which cause great damage. This population and a secondary one in Denmark, migrate to the Federal Republic of Germany, France, Switzerland and Italy, where they cause considerable problems in winter. Birds attack fish stocks in big rivers, lakes, estuaries, ponds which support fisheries. Problems are reported from lakes in Italy, big rivers and lakes in Switzerland, and open waters in the Federal Republic of Germany. This species is not mentioned as a problem in Belgium, Ireland, United Kingdom, Poland, Finland, Norway, Czechoslovakia, Austria, Cyprus, Israel.

Gulls: In Finland, Larus spp. have a period of active predation from the middle of July to September, when fish fingerlings have reached a length of 5–7 cm. This coincides with the main period of stocking in small rivers and lakes. In Ireland, the black-headed gull, Larus ridibundus, predates on elvers as they ascend into freshwater (March to June). Problems are also mentioned in Austria, but without further definition. This species is not mentioned as a problem in the Federal Republic of Germany, Denmark, Norway, Cyprus. In Czechoslovakia, it is supposed that this species mainly catches fish which are not in good health.

In Finland, herring gull (Larus argentatus), common gull (Larus canus), terns (Sterna paradisea, S. hirundo), act in the same way as L. ridibundus. They are not mentioned in other countries, except for the herring gull which causes problems in Hungary in October and in Italy throughout the year.

Red breasted merganser (Mergus serrator), merganser (M. merganser): Cited in Finland as having the same predation pattern as gulls. In Norway causes problems in salmon rivers. It is also present in the Netherlands and Ireland where the problem is not important.

Table 6

Total catch and number of professional and sport fishermen

Country	Number of Professional	Number of Sport fishermen	Catch (t)
Austria	220 [a/]	200 000	4 500 [b/]
Belgium		300 000	500
Cyprus		3 000	
Czechoslovakia		298 000	4 600
Denmark	300	400 000	637 [c/]
Finland			
France	300	4 500 000	45 000
Germany (Fed.Rep.)	1 329		2 500 [d/]
Hungary			9 000 [c/]
			4 500 [e/]
Ireland	307 (eel)		145.34
Israel			
Italy			9 459
Netherlands	650	1 000 000	3 000 [f/]
Norway	0–20	1 000 000	7 129 [g/]
Poland			20 000
Romania	950	205 500	14 200 [h/]
			4 000 [c/]
Switzerland	500	200 000	1 000 [e/]
United Kingdom		3 000 000	1 930–2 330 [i/]

[a/] Part-time
[b/] Two-thirds salmonids

c/ Professional
d/ 16 t eel, 21 t pike, 24 t pike-perch, 28 t carp, 11 t tench, 37 t salmonids, 69 t fingerlings
e/ Sport
f/ 2 000 t eel, 700 t perch, 300 t pike-perch
g/ 3 848 t brown trout, 1 004 t char, 307 t grayling, 391 t gwyniad, 586 tpike, 783 t perch, 65 t eel, 145 t others
h/ 75% cyprinds, 15% sheat fish, pike, pike-perch, chub, perch, 10% sturgeon and Danube herring
i/ salmon

In Romania, the bird predations are different. There are problems in the Danube Delta with pelicans, cormorants, grey heron, purple heron, night heron, gulls, terns, spoon bill, glossy ibis, great white heron, but their action is not precisely evaluated. Damage occurs essentially between March and September, especially in dry years when the level of the water is low and the fish are concentrated in small areas. There is no problem in natural open waters in Isreael and Czechoslovakia.

3. FISH DISEASES

See Part D: Fish Diseases. The assessment of this problem in open waters is very difficult. Distinction has to be made between the theoretic possibility that birds act as vectors of diseases, and their real action in the field, in comparison with other vectors or global conditions favouring the development of diseases. This second aspect was not dealt with in the responses to the questionnaire. Nevertheless, in most countries birds do not cause serious disease problems in natural fish populations of the open waters. They are mentioned as definitive hosts of parasites of the larval stages of fish (Ligula intestinalis, Diplostomum volvens, Neacus cuticola, Tetracotyle ovata), and as possible vectors of pathogenic bacteria and viruses. Thus they are assumed to transmit diseases from one water body to another, by droppings or injury to fish. But direct contamination and comparing with other vectors is not given, and for French specialists the problem is of minor importance as compared to the health conditions of fish, their food, the characteristics of water, the general conditions of management of fisheries, etc. For parasitic diseases, birds transmit eggs of parasites not to the fish but to an intermediate host (crustacea, mollusc), and densities of these, which directly transmit parasites to the fish, seems to be the most important factor. For other diseases, the action of birds is probably not very important (the body temperature of birds is not suitable for fish viruses), as compared to the probability of contamination from water or other fishes.

In the responses to the questionnaire, data are scarce on parasitic diseases. In Hungary, about 4.5% of 3–6 year old Abramis brama and Rutilus rutilus populations in Lake Balaton are infested by Ligula and Digramma, and 10% of the cyprinids in natural waters are infested by displostomosis. Some ponds or lakes bearly infested by diplotosma are only cited in this country and in Norway. Gulls are the essential definitive hosts of most parasitic species on fish. Inversely, birds may have a positive effect on fish diseases by taking sick or dead fishes as mentioned by the Federal Republic of Germany, the Netherlands, France for Ardea cinerea and Larus ridibundus (also a non-piscivorous bird: Milvus migrans), and for Phalacrocorax carbo in the Netherlands. In Romania and Italy, birds eat also sick, dying or recently dead fish.

4. BIRD PREDATOR POPULATIONS (LEGAL POSITION)

The status of piscivorous birds differs according to country, species, period and area. It may even differ with province in the same country as in Austria, where the grey heron is protected only in Salzburg and upper Austria. Information is lacking for some countries and it is not possible to describe precisely the general situation. Answers to the questionnaire generally concern only birds cited as causing problems; legal status of other species was rarely mentioned.

Table 7

Legal protection for piscivorous birds in EIFAC countries

Country	Ardea cinerea	Phalacrocorax carbo	Larus ridibundus	Larus argentatus	Larus canus	Sterna spp.	Mergus spp.	Alcedo atthis	Podiceps cristatus	Pelecanus sp.
Austria	P/N	P	N					N	N	
Belgium	P	P						P	P	
Cyprus	P	P	P	P	P	P	P	P	P	P
Czechoslovakia	P		P							
Denmark	P	P	N	N	N	P	N	P	P	
Finland			N	N	P	P	N			
France	P	P	P	P / N	P	P	N	P	P	
Germany (Fed. Rep.)	P / N	P	N			P	N	P		
Hungary	P / N	P	P / N	P / N	N	N	N	N	N	
Ireland	P	P	P					P	P	
Israel								N	N	
Italy		P								
The Netherlands	P	P	N	N	P	P	P	P	P	
Norway	P		N		N					
Poland	N	N	N	N	N	N	N	N	N	
Romania	P	N	N	N	N	N	N		N	P
Switzerland	P	N								
United Kingdom	P	P				P			P	

P = yes
N = no

Austria	All birds are protected except grey heron which may be shot in lower Austria. In upper Austria gulls are only protected from 15 April to 15 July.
Belgium and France	Grey heron, great cormorant, black-headed gull and kingfisher are totally protected throughout the year and there is no licence to shoot them on fish farms.
Federal Republic of Germany	The status of heron differs with federal states as follows: <u>Baden-Württemberg</u>: Grey heron and kingfisher are protected. Black-headed gull can be shot. <u>Bayern</u>: Grey heron is protected from 16 September to 31 October <u>Niedersachsen</u>: All birds are protected all year except gulls which are protected from 30 April to 16 July and coot which is protected from 15 January to 1 September. Licences can be given to shoot the following birds on fish farms: gulls, grey heron, great crested grebe and coot. <u>Nordrhein-Westfalen</u>: Kingfisher is protected. <u>Nordwürttemberg</u>: Grey heron is protected. Black-headed gull is protected from 1 May to 15 July. <u>Schleswig-Holstein</u>: Grey heron is protected, but licences can be granted to shoot a maximum of 8 specimens/year within 200 m of the farm. Common tern, kingfisher and osprey are protected. Black-headed gull can be hunted from 16 July to 30 April and common gull can be hunted from 16 August to 30 April. There is no licence for shooting protected birds on fish farms.
Ireland and the Netherlands	Licences are given on a short-term basis to shoot predatory birds where proof is forthcoming that there is a need for control, but success of these operations is not quantified and indiscriminated shooting was found to be of little benefit. Also in the United Kingdom, licences for shooting protected herons may be issued if damage is significant and other control methods are not adequate.
Denmark	Trout farms must legally have wires above the ponds. If there is still damage, grey heron, great cormorant, black-headed gull, common gull and herring gull can be shot all year round inside fish farms, but only by special licences. The same applies to the great crested grebe, although this species is not mentioned as a bird problem. Black-headed, herring and common gulls can be hunted otherwise from 1 September to 29 February. Other species cannot be killed even on fish farms.
Norway	Mergansers and gulls can be hunted during a short period of the year, and grey heron can be shot on fish farms. Hungary

	has a similar status for the grey heron and shooting black-headed gulls and herring gulls is permitted on fingerling ponds from 1 October to 30 November.
Romania	Predatory birds can be frightened or shot only at fish farms in the delta of the Danube, by governmental guards. An optimum number of predatory birds is conserved each year in the whole of the Danube Delta by partial destruction of eggs, frightening or shooting surplus birds.
Finland	All birds, even protected species, can be destroyed at fish farms with a special licence if they cause damage.
Poland	No species is protected in any area.

In open waters there are in general no indications that fish populations have changed due to bird predation. However, in the Netherlands, the feeding behaviour of the cormorant at the heavily fished feeding areas near the big colonies has changed, probably due to the increased number of cormorants. Formerly, cormorants fished mostly individually and preferred larger fish (eel, pike-perch). Now on the fishing areas of big cormorant colonies on Lake IJsselmeer "social fishing" by some hundreds and even thousands of cormorants together is a normal phenomenon. In this way cormorants are fishing jointly on shoals of small fishes, which were formerly not preyed upon. Today, 50% of the number of fish caught are smelt (Osmerus eperlanus), one may ask if this changed behaviour points to a modification of the fish population due to heavy fishing at a restricted area within flight distance of the colony.

The relation between increasing populations of piscivorous birds and legal protection is mentioned by France, Belgium, the Netherlands, Federal Republic of Germany and Denmark for great cormorant and grey heron. In the Netherlands, due to legal protection, the population of the great crested grebe has increased from 300 to 7 500 breeding pairs, the great cormorant from 1 200 to 11 000 breeding pairs and the grey heron to more than 10 000 breeding pairs. Otherwise in the Netherlands, under the influence of modification of habitat and pollution, some uncommon fish-eating birds which are not important to fisheries, have become scarce (kingfisher) or are decreasing in numbers (purple heron, little bittern). Conversely, in Austria grey heron and black-headed gull are not protected but are increasing in abundance, even "exploding" in some places, perhaps because they are more hunted in Yugoslavia, birds migrate to Austria. Nevertheless, factors affecting the population dynamics of birds are very complex and cannot be attributed solely to human disturbance.

5. MEASURES

Preventive measures to control damage by birds at large open waters are probably neither practicable nor effective, except with drastic measures on populations of birds in breeding sites, which are not used in western Europe (EEC particularly) because birds are now considered to represent a patrimonial value. In Romania, authorities reduce the egg number in the nests of the piscivorous birds, and also adult birds by shooting, with a certain success because these measures are repeated each year all over the delta of the Danube. Even in this country the problem of damage persists, and in Poland the destruction of nesting places is practised without apparent effect. To stop totally any damage, it would be necessary to suppress the entire population of birds, which is hardly possible. The only measure for protecting small areas from visits of birds could be by wiring which may be successful.

6. RESEARCH

There are two governmental working parties on the problem of piscivorous birds in France and Switzerland. A scientific working group also exists in Bavaria. The governmental working parties have published their final reports.

Previous to the report in France (Marion, 1983) there was a local study on a fish farm (trout culture) in western France (herons) and on fisheries (cyprinids) in Camargue. In 1985 a small study was also made on a fish farm in Alsace (herons). The French Government actually finances five important studies on herons, great cormorant and black-headed gull in several provinces (ponds in Brittany, between the Loire and Gironde, Arcachon, Camargue and ponds in Forez). The grey heron population dynamics is also being studied in a long-term programme, to determine the effect of protection of this species (several publications).

In Switzerland, six publications treat “heron problems” and an investigation concerning cormorant is being made. In the Federal Republic of Germany, the predation by herons was studied in Bavaria on carp ponds. Another study on measures to protect fish farms and ponds from herons was made in Nordrhein Westfalen. In the United Kingdom, a study was made on predation by herons in fish farms.

In Ireland, only the food of cormorants was studied in open waters. In the Netherlands, research has been done in 1939 and 1952 on the kind and extent of the cormorant problem on commercial fisheries on the IJsselmeer, and recently at a fish farm (Lelystad). In Belgium, studies on herons and kingfishers were made on predation and protection measures.

In Denmark, veterinary research was carried out on parasitic diseases transmitted by birds. Another study is being made on the possible damage to fisheries by great cormorant, based on the stomach contents collected by fishermen shooting these birds (coastal waters) and from birds drowned in nets (lakes). In Romania, systematic research is being done in the Danube Delta concerning the dynamics of the piscivorous bird populations as well as on their influence both in the open waters and in fish ponds. In Poland, predation and relation with diseases were not studied, but a study was made on the percentage of the food given to fish in farms which was consumed by ducks and bald coot (2–7%). In other countries (Austria, Czechoslovakia), no investigations have been made on these subjects.

Except for great cormorant in certian favourable conditions (the Netherlands, Federal Republic of Germany, France in Camargue, Romania), these studies have shown that predation on fishes in open waters by piscivorous birds is not very important, in comparison with losses through bad management, water problems, diseases and predatory fish species.

7. ECONOMICAL IMPACT

As can be seen from the replies of the questionnaire, bird damage in open waters is local (cormorants) and mostly not of great economical importance, except in some areas:

Denmark

With the exception of the cormorant, the damage by fish-eating birds to fisheries in open waters is considered negligible. In certain coastal areas professional fishermen are convinced that cormorants represent a serious problem for their trade. A research project has been initiated on the possible damage of this species based on stomach contents.

Federal Republic of Germany

Bayern: Economical losses for open water fisheries in Bavaria is indicated at 50% as a consequence of bird predation (especially by herons and mergansers). For the Kochelsee (650 ha) the amount of fish eaten by piscivorous birds was calculated to be 12.8 t/year (US$ 38 400).

Niedersachsen: The economical impact of bird damage on commercial fisheries in open waters is roughly estimated at DM 150 000/year.

Schleswig-Holstein: In the last few years an alarming situation has developed because of the rapid increase in the number of cormorants visiting Schleswig-Holstein in summer. Besides pond farms intensive management of fisheries on smaller lakes are highly endangered. A “visit” by a swarm of cormorants on those waters generally means the collapse of a fisheries enterprise, as the lake will be fished out totally within a short time. The owner of one fisheries enterprise on a small lake claimed damages due to cormorants of DM 75 000 in 1983.

More additional information is given in the article by Dr J. Deufel “Kormorane - ein problem für die fischerei” (Der Fischwirt, March 1984, 33, 19–22). In this publication the results of the national inquiry 1983 on cormorants have been taken together. At the moment the cormorant is no longer of local interest, but is seen potentially as the most important predator and a real danger for aquaculture enterprises in the near future.

Italy

It was difficult to collect sufficient data, but in Italy bird predation also seems to be a problem. Especially in waters with extensive fish culture, such as the well-known “Valli of Comacchio” with a total surface of 10 000 ha. Some data are available for Lake Sabaudia (central Italy) with a 400-ha area. The financial loss due to bird predation amounts to US$ 18 000/year, mainly caused by cormorants fishing on eel (October–March). Apart from the situation for Lake Sabaudia, the problem of cormorant predation is considerable for the other brackishwaters in Italy.

The Netherlands

A serious problem is caused by predation of the rapidly increasing cormorant population, strongly hampering the fisheries on Lake IJsselmeer and estuaries in the south-western part of the country. Due to total protection, the breeding population of the great cormorant has increased from 1 200 breeding pairs in 1954 to more than 11 000 breeding pairs today. The bulk is found around the IJsselmeer with a total of 10 000 breeding pairs (together 50 000 adults, non-breeding birds and young ones). This cormorant population which fishes on the IJsselmeer (185 000 ha), catches at least as much as the commercial fishermen (37 000 t) with a value of U$ 7 500 000.

Romania — Fish-eating birds cause important damage in the open waters. Outside the Danube Delta the damage is estimated in general at 5% of the yearly national production. However, for the most important fishing area, the Danube Delta (279 000 ha), the losses are much higher and reach up to 50% of the total production. In 1981 the losses of fish due to bird predation for this area were calculated at 4 000 t of a yearly production of 7 900 t. For 1981 the economical loss caused by birds in the Danube Delta was estimated to be leu 26.4 million (US$ 1.8 million).

II REVIEW OF REPLIES OF QUESTIONNAIRE - PART D: FISH DISEASE PROBLEMS RELATED TO BIRDS

K. Molnar - Veterinary Medical Research Institute, Hungarian Academy of Sciences (Budapest, Hungary)

Reports on fish diseases transmitted by birds were received from a total of 11 countries: United Kingdom, Ireland, France, Federal Republic of Germany, the Netherlands, Belgium, Denmark, Finland, Poland, Romania and Hungary, but other reports contained some data giving a total of 17 which contained data that could be evaluated.

Pond Fish Culture

All reports emphasize that birds cause significant damage by spreading diseases in pond farms. There are well substantiated data on the role of birds in transmitting parasitic fish diseases in pond farms. Observations confirm their role in the transmission of: Viral Haemorhagic Septicaemis (VHS), Infectious Pancreatic Necrosis (IPN), Spring Viremia of Carp (SVC), and bacterial diseases from one place to another. Of the parasitic diseases, the trematode Diplostomum spathaceum and the cestode Ligula intestinalis are the most important. The adults of Diplostomum live in the intestines of gulls, whereas their metacercariae occupy the eye of fishes. This parasite is the causative agent of lens cataracts of fish in numerous European countries. The larvae of Ligula intestinalis, a helminth colonizing the intestine of aquatic birds, cause significant damage to pond farm fishes in certain countries. Besides these two parasites which are spread all over Europe, other trematode metacercariae, e.g., the larvae of the black spot disease agent Posthodiplostomum cuticola, might give rise to problems in fish ponds. This disease is transmitted by herons. Infections caused by Diphyllobothrium dendriticum and D. norvegicum were reported from Finland and the Netherlands and Valipora sp. (Cestoda) spread by herons causes infection among pond farm fishes in Poland.

The stress caused by aquatic birds can be considerable. In ponds overrun by birds fish must hide, do not feed regularly and consequently suffer retardation in growth.

In winter ponds devoid of ice cover, grebes, diving ducks and goosanders cause significant damage and disturb the resting period for fish. Gulls might also do damage in these ponds by inflicting wounds with their beak on fish coming near to the surface or to the inflow because of other diseases or problems, such as, lack of oxygen. These wounds aggravate the primary disorder.

The most significant damage is done by gulls and terns during fishing out of the ponds. At such times these birds lift out numerous fish from the overcrowded fish population; since they are unable to consume the relatively large fish, they drop them back into the water repeatedly. The beak-inflicted skin injuries can give rise to fungal and bacterial complications and in Hungary and the Netherlands up to 100% of carp bear evidence of such damage.

Trout Culture

In trout culture bird-transmitted fish diseases have lesser importance. Lens cataract develop as a result of diplostomosis in most cases. In the affected farms, the fish population is protected by scaring away the birds or by covering the ponds with nets. In these farms, birds can cause damage primarily by introducing viral diseases.

Open Waters

In open waters, the major damage by birds is due to their role in spreading diplostomosis and ligulosis. Diplostomosis is spread by gulls (Laridae), whereas ligulosis is spread primarily by herons (Ardeidae). Black spot disease caused by Posthodiplostomum cuticola (Metacercariae) is spread by herons, the eye disease caused by Tylodelphis clacata is spread by grebes (Podicipinae), and Apophallus muehlingi and Metagonimus yokogawai metacercariases transmitted by gulls and terns are widespread in natural waters. Trout and coregonids in northern countries may develop severe infections by larvae of the cestodes Diphyllobothrium dendriticum and D. norvegium. Wounds inflicted by birds and the subsequently developing mycotic complications are frequently observed also on fish living in natural waters.

Additional information on this subject is given in Part C: Fish Diseases section.

III LITERATURE REVIEW - PROBLEMS CAUSED BY BIRDS AT INLAND WATERS AND FRESHWATER FISH FARMS

M.C.M. Beveridge - Institute of Aquaculture, University of Stirling (Scotland)

1. INTRODUCTION

This report forms part of the remit of the EIFAC Working Party on the Prevention and Control of Bird Predation in Aquaculture and Fisheries Operations. Its primary purpose is to review the literature on bird predation, although it also considers the broader aspects of bird/aquatic ecosystem interactions, particularly as they affect fish populations (e.g., disease transmission, trophic state, etc.). It is thus intended to complement the summary reports on the status of the problems experienced by EIFAC member states prepared from questionnaires.

The report sets out to determine the avian species involved, and to assess the economic losses incurred in open water fisheries, pond fish farms and trout farms. It also examines the effectiveness of various methods of control. The report draws heavily upon published data from within EIFAC member states, but also includes information from outwith this area, particularly on control methods.

2. BIRDS AND FRESHWATER ENVIRONMENTS

An examination of handbooks and field keys to European birds (e.g., Cramp et al., 1977, 1980, 1983, 1985) reveals more than 100 species, including divers, grebes, herons, cormorants, wildfowl, hawks, eagles, cranes, gulls, swifts, kingfishers and swallows which are associated with wetlands, using them as a source of food and/or shelter. Many of these species, however, are rare (e.g., Gavia adamsii, the white billed diver), whilst others, such as the white pelican Pelecanus onocrotalus are migrants, occurring in only a few of the EIFAC countries for limited periods of time each year. Yet others, such as the swift (Apus apus), have only minimal contact with water whilst in flight and tend to associate with water bodies only under certain circumstances, such as during a hatch of aquatic insects (Lack and Owen, 1955). These species are unlikely to have any serious adverse effect on fish stocks or fisheries.

A number of species, however, may be regarded as common, are widely distributed and have a strong association with wetlands, using them for both nesting and feeding purposes. Several other species, such as the crow, Corvus corone cornix, which exhibit opportunistic or scavening feeding behaviour, are attracted to fish farms (Keve, 1962) where dead fish and fish food may be readily available.

The impact of birds on the aquatic environment may be summarized as shown in Figure 1. Some of these impacts are minimal and are unlikely to have any significant effect on fish populations (e.g., habitat modification through nest building). However, other activities, such as feeding or roosting, may indirectly affect fish through their role in disease transmission and their impact on trophic state, whilst piscivorous feeding directly influences fish numbers and may even affect community structure.

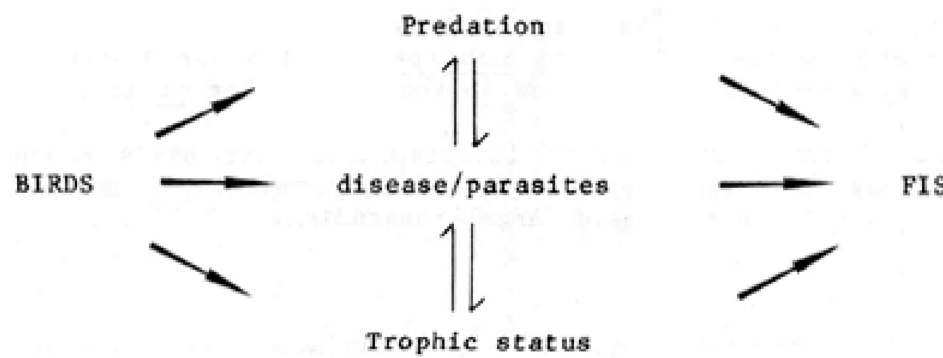

Figure 1 The effects of birds on fish

In this report, the impact of birds on trophic state, disease transmission and predation will be examined, and it concludes with a review of available methods for limiting adverse effects on freshwater fish communities.

3. PREDATION

Predation by birds may affect fish populations indirectly through competition for food, or directly through piscivory.

3.1 Plants

Most species of waterfowl rely predominantly on aquatic plants, belonging to the genera Chara, Potamogeton, Ceratophyllum, Lemna, Typha, Elodea and Phragmites for food (Gaevskaya, 1969). However, although they can under exceptional circumstances consume up to 90% of the annual macrophyte production (Uspienski, 1967, in

Dobrolowski, 1973), they usually account for only 2–3% of production (Dobrolowski, 1973; Dobrolowski, Halba and Nowicki, 1976). Consumption of aquatic plants on this scale by birds is unlikely to have any significant adverse effect on fish populations which generally use fringing macrophyte beds for breeding, nursery areas, shelter or foraging rather than as a direct source of food.

3.2 Invertebrates

Invertebrates (principally insects) play a dominant role in the diet of juvenile and adult dabbling ducks (Tribe: Anatini) during the summer months (Danell and Sjoberg, 1980) and are also an important component in the diets of divers, herons, smew, coots, gulls and kingfishers at certain times of the year or during certain periods of their life (see below). According to Dobrolowski, Halba and Nowicki (1976) invertebrates account for between 10% and 36% of the diet of wildfowl communities in Polish lakes, the birds consuming between 15 and 60 kg/ha of invertebrate production each year. The relative importance of invertebrates in the diet was found to increase with lake productivity.

Studies in Sweden by Eriksson (1979) and in Canada by Eadie and Keast (1982) have shown that goldeneye (Bucephala clangula) and perch (Perca fluviatilis) have a high diet overlap in terms of invertebrate prey type and size, and that there was a reciprocal density trend which could not be solely attributed to differences in habitat use between the two species. Competition for food between black duck (Anas rubripes) and brook trout (Salvelinus fontinalis) has also been demonstrated in the USA (Hunter et al., 1986).

In view of the quantities of invertebrates that birds consume, it is likely that they do compete with fish for prey, although the importance of competition and its effects remain largely unstudied.

3.3 Fish

The principal species of piscivorous birds associated with inland waters are summarized in Table 8. Amongst the divers (Family: Gaviidae), the red-throated (Gavia steluata) and black-throated (G. arctica) are commonest, and occur in remote inland waters during April–September/October, usually in small numbers. Both species feed principally on fish, including salmonids, roach (Rutilus rutilus), bleak (Alburnus alburnus), dace (Leuciscus leuciscus), perch and carp (Cyprinus carpio) (Madsen, 1957).

All grebes (Family: Podicepedidae) feed on fish, although the great-crested grebe (Podiceps cristatus) is the commonest and most widely dispersed of the European species and has a more piscivorous diet than other members of the family. It tends to inhabit large lakes during March–October, except in central European countries such as Switzerland where it overwinters in ice-free areas, and feeds on a wide range of small (3–21 cm; mean size= 13 cm) fishes (Geiger, 1957). Usually it prefers more than 1 ha per pair of birds, although occasionally several thousand pairs have been recorded at open water sites (Jacoby, Knotzsch and Schuster, 1970; Vlug, 1974; Geroudet, 1974).

There are several races of cormorant (Phalacrocorax carbo), including North Atlantic (Phalacrocorax carbo carbo), Eurasian (Phalacrocorax carbo sinensis), Moroccan (Phalacrocorax carbo maroccanus) and African (Phalacrocorax carbo lucidus) races, all of which are almost exclusively piscivorous in feeding habit. Phalacrocorax carbo carbo is non-migratory and has a large coastal distribution in western Europe, although it can occur up to 60 km inland (Mills, 1965). Phalacrocorax carbo sinensi, on the other hand, is a continental, largely migratory race, which now occurs widely throughout Europe, from east to west, and from north to south (Hansen, 1984). In inland areas both races are found on or around lakes, reservoirs, fish ponds, open water areas in swamps and broad sluggish areas of rivers, where they feed on a wide range of fish species (Madsen and Sparck, 1950; van Dobben, 1952; Mills, 1965; West, Cabot and Greer-Walkob, 1975; McIntosh, 1978; Ranson, 1982; Moerbeek et al., 1987). Typically, the cormorant is a solitary feeder, although it sometimes feeds in loose flocks (Hachler, 1959).

The pygmy cormorant (P. pygmeus) is much smaller, less common and extremely restricted in range, although it too feeds largely on fish. Two entirely piscivorous species of pelican, the white pelican (P. onocrotalus) and the dalmatian pelican (P. crispus) occur in southeastern Europe and share similar habitats although the latter is less exclusively found in lowland and coastal areas. Both species exhibit a variety of feeding behaviours, from cooperative to solitary, and feed on a wide range of fishes (Korodi Gal, 1964; Bauer and von Blotzheim, 1986; Brown and Urban, 1969). The dalmation pelican, which is the larger of the two, can take pike (Esox lucius) up to 50 cm in length (Cramp et al., 1977).

Table 8

Summary of principal piscivorous species feeding on European inland water fishes
(data taken from Cramp et. al., 1977, 1980, 1983, 1985)

Species	Distribution	Habitats	Movements	Food
Red-throated diver (Gavia stellata)	Northern Europe, Finland N. USSR, Norway, Sweden Iceland, Scotland	Small pools,large lakes. Prefers shallow water bodies	Migrating/dispersive. April–September inland. Overwinters on coast	Principally fish (salmonids/ roach/dace/bleak) frogs and invertebrates
Black-throated diver (G. arctica)	Northern Europe, similar to G. stellata	Prefers large, open, deep lakes	Migratory/dispersive. April–September inland. Overwinters on coast	Chiefly fish (perch/trout/ bleak/dace/roach/carp) also frogs, insects, snails
Litte grebe (Tachybaptus ruficollis	Europe, NW Africa, Turkey and Israel. Not further N than S Sweden	Adapted to wide range habitats/lakes/reser voirs/ponds/sewage/ canals/rivers/streams	Resident/dispersive/ migratory. Generally found inland, migrates coast if winter severe	Fish form 40–50% adult diet in winter and include carp/ gudgeon/minnow/roach/dace /rudd/bream bleak/perch
Great-crested grebe (Podiceps cristatus)	Widely distributed in most of Europe, except for north	Cool-cold standing freshwaters, natural/ artificial + fishponds	Migratory/dispersive. Shifts from inland waters-sea in winter	Chiefly fish, including roach/bleak/gudgeon/perch/ salmonids
Cormorant (Phalacrocorax carbo)	Coastal areas of N and W Europe. Also central and SE Europe	West Europe, largely coastal. East Europe/ Netherlands breed near large inland waters	Migratory/partially migratory/dispersive, according to popula tion	Almost exclusively fish. In inland waters feed on eel/roach/ruffe/pike-perch/bream /perch/rudd/tench/salmonids
Pygmy cormo'rant (P. pygmeus)	Restricted range. Occurs small no. in Yugoslavia Greece/Romania/Turkey	Open standing of slow flowing freshwater/rice fields/swamps/floodlands	Migratory/partially migratory/resident populations	Chiefly fish including rudd/pike/carp/roach/loach/ bitterling/tench
White pelican (Pelecanus onocrotalus)	SE Europe/Romania/Greece/ Turkey/USSR	Low-lying/shallow warm water bodies/river deltas/wetlands	Migratory/non-disper sive except in tropics	Almost exclusively fish + roach/carp/bream/rudd/bleak/ pike

Dalmation pelican (P. crispus)	SE Europe, especially Romania/Bulgaria/Albania/ Turkey/Yugoslavia/USSR	Similar to often shared with P. onocrotalus also tolerates hilly terrain with small open waters	Migratory/partially migratory	Entirely fish, including carp/perch/asp/roach/pike/ tench
Bittern (Botaurus stellaris)	Widely distributed in E Europe, particularly W. Not in Scandanavia	Lowland swamps, densely vegetated wetlands in middle latitudes <200 m	Partially migratory/ dispersive/resident	Chiefly fish (pike/carp/ roach/eels/tench) also frogs, mice and insects
Little bittern (Ixobrychus minutus)	Similar to but more widely distributed than B. stellaris	More adaptable than B. stellaris occupying swamps/rivers/fringes	Migratory/dispersive	Mainly fish (pike/carp/ roach/eel) also amphibians and insects
Night heron (Nycticorax nycticorax)	Patchy distribution throughout middle/south latitudes. In decline in many areas	Warm/temperate/sub-tropical zones, occupying wide range habitats upto 2 000 m including lentic and lotic sites	Migratory/dispersive. Few in Europe from November–February	Chiefly insects, fish (carp/ eel/tench/chub) and amphibians
Squacco heron (Ardeola ralloides)	Very patchy distribution in S. Europe. In decline in many areas	Lowland valleys/wetlands/deltas/estuaries. Prefers pools/ponds/canals/ditches with vegetation	Migratory/dispersive. Overwinter in Africa	Small (10 cm) insects, amphibians, fish (bleak etc.)
Little egret (Egretta garzetta)	Very patchy distribution S. Europe. Recovering	Usually in lowland shallow lakes/pools/gently flowing rivers. Sometimes coastal areas	Migratory/dispersive. Majority overwinter in Africa	Mainly small (12–15 cm) amphibians, insects, fish (tench/carp/roach/loach)
Great white egret (E. alba)	Rare, breeding populalations in USSR/Turkey/ Hungary/Czechoslovakia	Largely restricted to extensive wetlands and margins of fresh water in lowland regions	Partially migratory/ dispersive. Over winters around Adriatic/Mediterranean	In wet season, chiefly fish (sunfish/carp/tench/trout). In dry season insects
Grey heron (Ardea cinerea)	Widely distributed midlatitudes and coastal areas of Scandanavia	Mainly lowland (<500 m) Prefers lotic/lentic shallow fresh waters, with trees close by	Migratory/partially migratory/dispersive. Most European popula tions overwinter in southern/western areas	Variable. Chiefly fish (1–25 g), amphibians, small mammals
Purple heron	Patchy distributed	Shallow/eutrophic waters	Migratory/dispersive	Fishes singly on fish

(A. purpurea)	throughout central and southern Europe	with sand/silt bottom and emergent vegetation	Most overwinter in Africa south of Sahara	(bream/carp/perch) and insects
Black stork (Ciconia nigra)	Patchy, in eastern and southern Europe	Undisturbed forest areas with streams or pools; occasionally large lakes	Migratory/dispersive. Overwintering in south Africa/China/India	Chiefly small fish (loach/ perch/eel/burbot), also insects, amphibians, reptile
Smew (Mergus albellus)	USSR. Occasionally overwinter in central and western Europe	Prefers mature woodland near lentic water bodies Occupy ponds/reservoirs	Migratory, although routes little known	Mainly fish (salmon/trout/ fry/gudgeon/roach). Insects in summer and Autumn
Red-breasted merganser (M. serrator)	Widely distributed in N. Europe, especially UK and Scandanavia	Wide range, including oceanic/temperate forest/estuarine. Wintering birds prefer marine habitats	Migratory/partially migratory. Most over winter in S. Europe	Primarily fish (salmonids/ eels/lamprays/minnows/carp)
Goosander (M. merganser)	Similar to M. serrator	Upper basins of rivers/lakes in forest/mountain areas in close proxi mity to mature trees	Migratory/partially migratory. Overwinters in NW Europe/Black Sea	Chiefly fish, with some preference for salmonids
White-tailed eagle (Haligeetus albicilla)	Mainly eastern/coastal/northern Europe including Iceland	Sea coasts/rivers/lakes and wetlands	Resident/migratory/ dispersive, according to latitude and age-class	Hunger, scavenger, food pirate, fish (pike/roach/bream/ perch), birds, mammals and carrion
Osprey (Pandion haliaetus)	Eastern and northern Europe/Scotland/Germany. A few Mediterranean populations	Continental areas near clear, unpolluted waters with ample medium-sized fish. Some coastal popu lations in Mediterranean	Migratory. Overwinter mainly in Ethiopian Africa	Wide range fish (salmonids/ pike/perch/road) captured by diving

Black-headed gull (<u>Larus ridibundus</u>)	Widely distributed throughout N/C/E Europe. Recently in Spain and Italy	Wide range lowland/upper lowland habitats, always near shallow, calm water	Migratory to E and N dispersive/partially migratory elsewhere.	Mainly animal material esp. insects and earthworms. Food pirate and scavenger. Small fish, live/dead shallow wat.
Common gull (<u>L. canus</u>)	N and E Europe and central western Europe	Generally lowlands continental to coastal avoid frozen and desert conditions	Migratory. Overwinter in W. Europe coastal areas around Black Sea	Chiefly terrestrial/ aquatic insects, fish (salmon parr). Direct predation, also food piracy and scavenging
Lesser black-backed gull (<u>L. fuscus</u>)	Northern Europe (breeding populations)	Prefers flat or sloping sites under short vege tation in temperate and boreal zones, also buildings	Largely migratory. Winter range extends from UK/Black and Caspian Seas/W and E Africa/Mediterranean	Omnivorous. Predation, scavenging and piracy. Fish (roach/perch/bleak/pike/ salmon)
Herring gull (<u>L. argentalus</u>)	Commonest and most widespread of large gulls in W. Paloeartic. Spread throughout W. Europe increasing in range especially inlands	Basically marine, colo nies recently estab. inlands, including buildings, lake shores and islands	Migratory in northern Scandinavia and USSR. Elsewhere, resident or dispersive	Predator, food pirate, scavenger. Wide range food, invertebrates, amphibians, fish (roach/perch/pike) and mammals
Common tern (<u>Strerna hirundo</u>)	Widely distributed throughout coastal areas W. Europe, also continental central and eastern Europe	Along coasts and inland fresh waters in boreal temperate/steppe/semi-desert/Mediterranean. Generally lowland	Migratory throughout most W. Europe. Overwinters western sea-board of Africa, Black and Caspian Seas, Mediterranean	Chiefly marine fish. Freshwater fish include roach/ perch/salmonid, etc.
Little tern <u>S. albitrons</u>)	E. Europe, coastal north, W. Europe, Mediterranean. Few inland populations in W. or central Europe	Frequently coast dwel ling, also major rivers and some lakes	Migratory. Many over winter in Africa	Small fish, including roach, rudd, carp
Kingfisher (<u>Alcedo atthis</u>)	Widely dispersed throughout Europe except N. Scandinavia and Scotland	Close to clear, ice-free still or gently flowing fresh or brackishwater. Lowlands (<650 m)	Mainly migratory in N. and central USSR/partially migratory in central Europe/dispersive and resident in W. Europe and Mediterranean	Principally small fish (loaches/sticklebacks/ minnows, etc.), also insects rarely crustaceans and molluscs

The family Ardeidae is comprised of bitterns and herons. The bitterns (Botaurus stellaris and Ixobrychus minutus) are only patchily distributed in western Europe, occupying lowland wetlands. They are solitary, crepuscular birds which feed in shallow waters on a wide range of insects, amphibians and fish (Vasvari, 1938; Cramp et al., 1977; Gnetz, 1965; Bauer and von Blotzheim, 1986). The sub-family Ardeinae contains both egrets and herons and includes the little egret (Egretta garzetta) and great white egret (E. alba) and four species of heron (the night heron, Nycticorax nycticorax; the squacco heron, Ardeola ralloides; the grey heron, Ardea cinerea; the purple heron, A. purpurea) which commonly occur in EIFAC member states. All species feed on a wide range of fishes, although the squacco heron and little egret generally only take small (15 cm) individuals (Vasvari, 1938; Cramp et al., 1977; Vasvari, 1954; Dementiev and Gladkov, 1957; Valverde, 1955; Schlegel, 1964; Bauer and von Blotzheim, 1986; Muller, 1984).

Among the storks (Family: Ciconiidae), the black stork (Ciconia nigra) is the most piscivorous, feeding on a wide range of small (9–25 cm) fishes, which it catches by stalking, either singly or in small groups (Dementiev and Gladkov, 1957; Bauer and von Blotzheim, 1986).

A number of wildfowl species, including the smew (Mergus albullus), redbreasted merganser (M. serrator) and goosander (M. merganser) feed chiefly on fish. The smew tends to feed in small flocks and takes a wide range of small fishes, usually 3–6 cm, occasionally 10–11 cm (perch, carp) and rarely up to 29 cm (eel) in length. It modifies its diet in the summer to take advantage of aquatic insects (Dementiev and Gladkhov, 1957; Madsen, 1957; Doornbos, 1979). The meganser and goosander exhibit similar feeding behaviours and have similar dietary preferences. They feed in pair or flocks, often cooperatively, on small (<10 cm) fish (Madsen, 1957; Mills, 1962, 1962a; Nilsson and Nilsson, 1976).

There are three species of fish eagle (Family: Accipitridae, Genus Haliaeetus) which occur in Europe; the African fish eagle (H. vocifer), Pallas' fish eagle (H. leucoryphus) and the white-tailed eagle (H. albicilla). However, only the latter is common, the other two species being occasional visitors (Cramp et al., 1980). The white-tailed eagle is a very versatile hunter and takes a wide variety of prey, choice being determined by habitat and availability. In some areas fish are taken primarily during the spring and summer months, but account for less than half of the food ingested (Fischer, 1959 in Cramp et al., 1980; Willgohs, 1961; Glutz von Blotzheim, Bauer and Bezzel, 1971; Olsson, 1972), whilst in other areas, fish are taken more often and comprise at least 50% of the food taken at certain times of the year (Kasparsson, 1958 in Cramp et al., 1980; Bergman, 1961). A wide range of fish species is taken, usually in the 05-3.0 kg range, and the most common method of predation is by snatching from the surface.

The osprey (Pandion haliaetus) has a more continental distribution than the white-tailed eagle and feeds almost exclusively on fish which it catches with its talons during shallow (1 m) dives. A wide range of freshwater species are taken and choice is determined by availability, size and behaviour of prey (Curry-Lindal, 1969; Glutz von Blotzheim, Bauer and Bezzel, 1977; Nilsson and Nilsson, 1976; Hakkinen, 1978). Ospreys have also been reported taking fish from carp and trout ponds (Schnure and Thumann, 1961; Deckx, 1978; Mills, 1979).

There are several species of gull (Family: Lariidae), including the black-headed gull (Larus ridibundus), the common gull (L. canus), the lesser black-headed gull (L.

fuscus) and the herring gull (L. argentatus), which are increasingly associated with inland, continental sites, and which take fish as part of their diet. Inland populations of black-headed gulls feed on insects and earthworms for much of the year, but will also take fish (including sick and dead individuals), particularly during the winter and early spring months. They generally only take fish from shallow waters, or which are swimming just below the surface, and have been reported feeding at fish ponds (Keve, 1962; Cramp et al., 1983; Mills, 1964, 1980; Harris, 1965; Vernon, 1972). The common gull is regarded as primarily a ground-foraging species (Vernon, 1972), but has occasionally been reported taking fish (e.g., Nilsson and Nilsson, 1976). In a small sample of stomach contents examined between Apirl and June, Mills (1964) found that 53% contained salmon parr. The lesser black-backed gull has been reported feeding on a wide range of freshwater fishes, although there is little quantitative data. Goethe (1975) observed that one Finnish population fed almost exclusively on roach and perch during the summer months.

There have been numerous studies of the diet of herring gull (Cramp et al., 1983). Studies of inland populations in southern Sweden show that a high proportion (50%) of the stomach contents are comprised of freshwater fish (Andersson, 1970; Nilsson and Nilsson, 1976). They have also been recorded at fish farms (Mills, 1979; Ranson, 1982).

Inland populations of two species of tern, the common tern (Sterna hirundo) and little tern (S. albifroms) are widely reported as taking small (2.5–8 cm) freshwater fishes (Bauer, 1965; Lemmetyinen, 1973; Nilsson and Nilsson, 1976).

The kingfisher (Alcedo atthis) is a small, largely piscivorous bird which preys on a wide range of small (usually 3–5 cm) fishes in shallow (1 m) water, either by diving from a perch or by hovering before diving (Hallet, 1977, 1978, 1982; Iribarren and Nevado, 1982).

The above account summarized the principal species of piscivorous birds feeding in European wetlands. However, their economic importance will depend upon the quantities and quality of fish consumed and the intensity of predation at different sites.

The food consumption of birds can either be assessed from field data or from studies of captive birds, and there are disadvantages associated with both methods. The former is usually determined by examination of the gut contents of birds which have been shot, or from regurgitates or from pellets. Birds which are shot often regurgitate food, thus leading to underestimates of fish consumed, whilst it is often difficult to recover regurgitates or pelleted rejecta for analysis. Studies of captive birds are also likely to give underestimates of the quantities of fish consumed since the energy requirement of tree-living birds are some 20–50% higher than for captive birds (Kale, 1965; Wilson and Harmeson, 1973).

Quantitative data on the food consumption of various piscivorous birds are summarized in Table 9. Consumption can be seen to vary almost 100-fold between small birds, such as the kingfisher (average adult weight = 36–46 g) which consumes around 18 g of fish per day, and large birds, such as the white pelican, which can weight up to 11 kg and which can consume 1 600 g of fish in one day. Moreover, smaller birds tend to consume smaller fish which are usually of less economic importance. Thus it would seem that piscivory by the larger species is likely to be of greatest economic importance. However, many of the species isted in Table 9 are unlikely to have a serious impact on commercially important fish stocks or fisheries. For example, the white pelican which nests in large colonies of several hundred thousand and communally feeds on a diet almost exclusively based on medium-sized fish (see above), is comparatively rare, and there are fewer than a dozen colonies mostly sited in Romania, Greece, Turkey and the USSR. Moreover, the species does not tolerate proximity to man and favours areas guarded against disturbance by natural barriers, such as extensive reed beds. Whilst it may well have a major impact on the fishes of certain water bodies, it is unlikely to be a serious competitor with man for these resources.

Table 9

Quantitative estimates of daily food consumption by adult piscivorous birds

Species	Method of assessment	Amount (g day^{-1})	Amount (% body wt. day^{-1})	References
Great-crested grebe	Captivity	150–250	20	Geiger, 1957
Cormorant	Field	425–700	11–17	van Dobben, 1952; Mills, 1965; Linn and Campbell, 1986
White pelican	Field and captivity	900–1600	9–16 (est.)	Brown and Urban, 1969; Andone et al. in Cramp et al., 1977; Din and Eltringham, 1974
Dalmatian pelican	Field	1125–1270	22–24 (est.)	Dementiev and Gladkov, 1951; Korodi Gal in Cramp et al., 1977
Bittern	Captivity	-	20	Lundevall, 1953
Grey heron	Field	330–500	18 (est.)	Creutz, 1958; Junor, 1972; Cook, 1978; Meyer, 1980
Goosander	Captivity	-	18–27	Latta and Sherkey, 1966
White-tailed eagle	Field	500–600	9–15 (est.)	Willgohs, 1961
Osprey	Field	200–400	-	Schnurre and Thumann, 1961; Nilsson and Nilsson, 1976
Herring gull	Field	100–200	-	Spaans, 1971
Pied kingfisher	Field	18	25	Tjomlid, 1973

Other species, such as the bittern, also tend to feed in areas not exploited for fishing by man, such as marshes and swamps, and take small fish of little economic importance.

Some species, such as the osprey and white-tailed eagle, which have a wide distribution, are, nevertheless, comparatively rare. Moreover, they feed singly or in pairs and range over a wide area in search of food and are thus unlikely to seriously deplete the fish stocks of any single water body. This is confirmed by studies conducted at Lake Mockeln, southern Sweden, by Nilsson and Nilsson (1976), who showed that although the osprey was the only avian species whose diet consisted solely of fish, it only accounted for 4.6% of the annual fish consumption by the bird community.

Larger, more valuable, fish tend to be taken by the larger bird species (see above). However, evidence from the literature suggests that birds take very few fish greater than 20 cm (Nilsson and Nilsson, 1976). As recreational and commercial fisheries tend to concentrate on fishes which are larger than this, there is likely to be very little direct competition between birds and man for fish, although predation of small fish by birds may well have a marked impact on recruitment of older year classes (Backiel and Le Cren, 1967).

Species which are likely to have greatest impact on commercially important fishes of European inland waters, in view of the degree of reliance on piscivory, the quantities and quality of fish consumed, their numbers, distribution and feeding behaviour, are the great crested grebe, cormorant, grey heron, merganser and goosander.

Unfortunately, there have been few quantitative studies of the effect of bird predation on fish communities or fisheries. At Lake Mockeln, Sweden, Nilsson and Nilsson (1976) recorded 12 piscivorous bird species and the most important species, in terms of the proportions of fish consumed by the bird community throughout the year, were the goosander (62%), great crested grebe (10%), and grey heron (10%). Fish consumption by birds was estimated to be three times greater than that taken by man from the lake (Figure 2). However, the authors calculated that this was only equivalent to half of the amount that was consumed by the piscivorous fishes.

Most studies of the effects of cormorant predation on fish populations and fisheries of open waters have concluded that it has little, if any, serious long-term impact. Only one study to date, at Lake Constance in Germany, has shown that there may be an adverse economic effect (Deufel, 1984). Van Dobben (1952) concluded that cormorants had only a minor impact on open water fish populations in the Netherlands. More recently, McIntosh (1978) observed large numbers (up to 4.5 km^2) feeding and roosting on the lower reaches of the River Tweed in Scotland. However, although it was found that they took considerable quantities of fish (650–700 g/bird/day), mostly small salmonids, it was concluded that predation by the birds was unlikely to significantly affect salmon catches by anglers and netsmen.

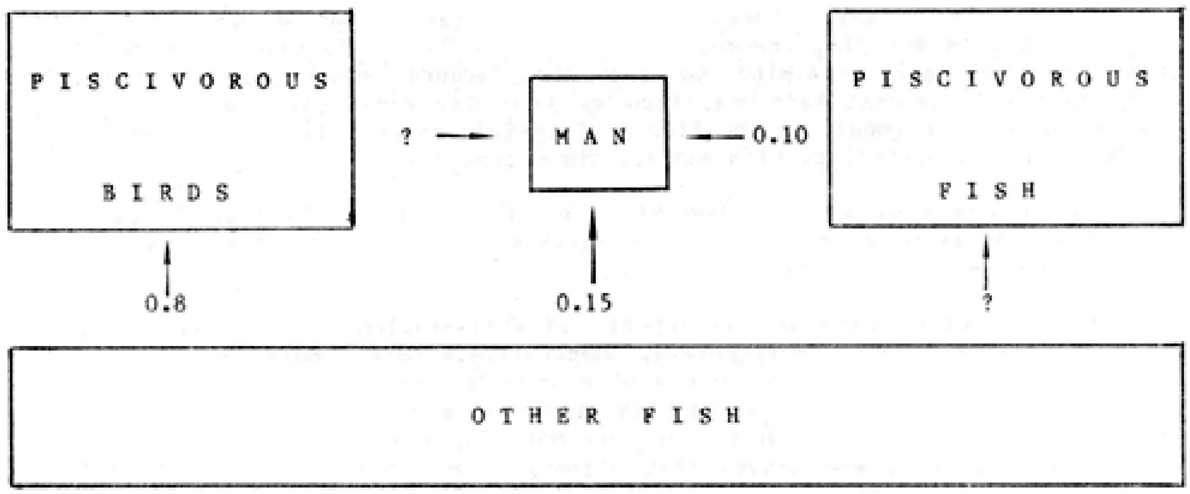

Figure 2 Relationships between fish, birds and man in Lake Mockeln, Sweden. Flow in $g/m^2/year$ (redrawn from Nilsson and Nilsson, 1978)

Studies of cormorant predation at open waters in Australia have shown that damage to fisheries is either negligible (Mattingley, 1927; Serventy, 1938; Mack, 1941) or, if it occurs, is localized and transitory in nature (Stead, 1954; Llewellyn 1983). In Lake Malawi, Africa, cormorant predation accounts for 21.63 kg/ha^2 of fish production in the southeast arm of the lake, or 20% of the standing crop available prey in the area (Linn and Campbell, 1986). Cormorant consumption was equivalent to 5.5% of the total taken by man from the lake. Moreover, there was very little overlap between the cormorant's diet and the species taken by the commercial fishery, and the authors concluded that this level of avian exploitation could probably be sustained indefinitely by the fish community.

The limited studies of heron predation that have been carried out have also suggested that it has little, if any, impact (Kramer, 1984).

Mergansers and goosanders have been reported by several researchers as having a marked adverse effect on salmon stocks and fisheries (White, 1957; Mills, 1962, 1962a, 1964; Elson, 1962). Whilst Mills clearly demonstrated the importance of salmon parr in the diet of the two species in Scotland, he did not quantify their impact on fisheries. Elson (1962), working on the River Pollett, New Brunswick, Canada, showed that goosander abundance was related to parr density and that greatly increased plantings of hatchery-reared under-yearlings did not result in proportional increases in smolts (Table 10). Since smolt output is related to returns of adult migrating salmon (Huntsman, 1941), it was concluded that the fishery would suffer.

Table 10

Smolt production from known plantings of hatchery-reared under yearling salmon in a 18 km experimental area of the Pollett River Canada (from Elson, 1962; Murton, 1971)

	Year of planting	Number of under-yearlings planted	Parr one year after planting	Total smolts produced from planting
No bird control				
	1942	16 000	3 000	2 000
	1943	16 000	2 000	1 000
	1945	249 000	12 000	5 000
Control of birds				
	1947	273 000	25 000	22 000
	1948	235 000	45 000	14 000
	1949	243 000	39 000	19 000
	1950	246 000	57 000	24 000

In conclusion, bird predators rarely seem to adversely affect open water fish stocks and fisheries, even when they take comparatively large numbers of fish, unless bird densities are unusually high. From a survey of the literature on factors regulating the density of piscivorous birds, the most important, other than geography, climate, season or time of day, is prey abundance (Elson, 1962; Nilsson and Nilsson, 1976; Mace, 1983; Barlow and Bock, 1984; Eriksson, 1985, 1986). Although the abundance of fish is principally determined by trophic state (Henderson, Ryder and Kudhongania, 1973; Adams, Kimmell and Ploskey, 1983), it can also be affected by pollution, such as acid rain (Eriksson, 1984), and by management. Stocking of open waters with hatcheryreared fishes can dramatically increase the number of avian predators and the consequent predation of fish, as studies in Canada and Australia have clearly demonstrated (Elson, 1962; Mace, 1983; Barlow and Bock, 1984).

Attacks by piscivorous birds on captive fishes have been widely reported from fish farms and hatcheries in Europe and North America (Cottam and Uhler, 1936; Lagler, 1939; Pough, 1941; Scanlon, Helfrich and Stultz, 1978; Mills, 1979; Meyer, 1980, 1981, 1982; Martin, 1982; Marion, 1983; Im and Hafner, 1984; Moerbeek et al., 1987). Indeed, from a survey of 38 fish farms in Scotland, only 13% of respondents claimed that some predation by birds did not occur (Mills, 1979). However, care must be taken to distinguish between birds which visit fish farms and birds which successfully take fish.

Most of the birds reported feeding on open waters have also been observed at fish ponds: the exceptions are those species which avoid proximity to man, such as divers, although others, such as osprey, which is also wary of man, have been recorded fishing at ponds (Schnurre and Thumann, 1961; Deckx, 1978; Mills, 1979). Birds other than piscivores, attracted by the availability of food, have also been reported. These include crows (C. c. cornix, C. c. corone), ducks (A. platyrhynchos) and gulls (L. ridibundus, L. argentatus) (Keve, 1962; Mills, 1979; Ranson, 1982), although the latter are also known to take fish (Mills, 1980).

The most important piscivorous species, in terms of economic damage, are the cormorant and heron. Other species, such as kingfishers and gulls also take fish but, although there are no published data, it is unlikely that they have any serious economic effect in view of the numbers likely to visit farms, their daily food requirements and the sizes of fish that they take (see above).

Heron predation at fish farms has been studied by Hafner and Moser (1980); Meyer (1980, 1981, 1982); Ranson (1982); Ranson and Beveridge (1983); Utschick (1983); Marion (1983); Draulans and van Vessem (1985, 1985a); van Vessem, Draulans and de Bont (1985). These studies show that the number of herons visiting farms tends to increase from February through to August, and then again during the winter months and that birds will travel several kilometres from their nest site/roost site to the farm. Early in the season the majority of visiting birds are breeders, whilst from June onwards, dispersing juveniles predominate. There are two peaks in activity - at dawn and sunset, although visits to water may be restricted to clear nights with good weather. The typical solitary feeding behaviour of the heron is less evident and in excess of 40 birds have been observed at any one farm (Meyer, 1981; Draulans and van Vessem, 1985). Catch rate is highest immediately after arrival and is higher in small rather than large flocks. Fish of 150–250 g are preferred.

From Meyer's work it is apparent that the economic impact of heron predation on pond-based fish farms depends upon farm location, production, pond dimensions and layout, and management. Farms close to heronries are most at risk and well stocked, shallow ponds with gently sloping banks, situated close to trees are most susceptible to predation. At the study farm, Meyer estimated that 4 000 lb of trout consumed by herons between April and August, representing a loss of £3 200, and a further 2% of stock (£130) were rejected for sale due to damage. Studies of economic losses at Danish trout farms have also been made by Moller and Olesen (1984).

Ranson (1982) and Ranson and Beveridge (1983) concluded that few, if any, fish were successfully taken by herons from a cage rainbow trout farm, but they observed that up to 7% of stock bore marks which were attributable to attacks by the birds. The proportion of damaged fish was found to vary with size, mesh size and time spent in the cages.

Studies of cormorant predation have been carried out at a pond-based farm near Lelystad, close to IJsselmeer, the Netherlands (Moerbeek et al., 1987). The farm has 218 ha of ponds which are used to rear both grass (Ctenopharyngodon idella) and common carp. A large colony (approximately 4 500 pairs) of breeding cormorants, first established in 1978, and an additional number of non-breeders, is situated some 13 km from the farm.

Cormorants were observed successfully capturing fish up to 550 g in weight, but were also shown to damage fish of up to 700 g. Losses due to bird predation were estimated by comparison with pre-colony figures and with losses from small, experimental ponds which were carefully protected. Losses during 1970–77 varied between 10 and 25%,. However losses from 1979 onwards, directly attributable to cormorants, were as great as 97% representing a huge economic loss.

In Australia predation of stocked farm dams by cormorants could account for up to 50% of fish (Barlow and Bock, 1984).

A study of cormorant predation at a cage trout farm in Scotland by Ranson (1982) and Ranson and Beveridge (1983) concluded that it was unlikely that the birds were successful in capturing fish, although up to 6% of stock in a cage bore marks consistent with cormorant attack.

In conclusion, it seems that pond-based fish farms can suffer heavy losses from cormorant and heron predation, particularly if the farm is situated close to a breeding or roosting colony. However, it must be borne in mind that the losses incurred at Lelystad (Moerbeek et al., 1987) are unusually high due to close proximity to an exceptionally large breeding colony. Studies of cormorant predation elsewhere (e.g., Im and Hafner, 1984; Deufel, 1984) suggest that losses are usually much lower. Bird predation does not appear to be a particularly serious problem at cage fish farms.

4. BIRDS AND TROPHIC STATUS

It has been widely observed that there is a relationship between bird species and numbers and the trophic state of a water body. For example, significant correlations between numbers of swans (Cygnus olor) and grebes and trophic state have been reported for Bavarian lakes by Utschick (1976). However, such observations do not necessarily mean that the birds have had any significant effect in determining trophic state.

The role of birds in determining the nutrient status of a water body will depend upon the feeding behaviour, seasonal abundance and community organization of the species. Many species spend a large proportion of their life on a particular water body, nesting and rearing their young and overwintering there, as well as relying upon it as a source of food.

Whilst birds which nest and feed on water bodies, such as grebes and coots, affect nutrient cycling within the water body (Dobrolowski, 1973; Dobrolowski, Halba and Nowicki, 1976) (see below also), birds which congregate in large numbers for extended periods of time and which forage for food outwith the immediate vicinity of the water body are most likely to have a marked effect on nutrient status through the importation of allochthonous materials. Many species of wildfowl (Family: Anatidae) forge for terrestial, as well as aquatic food items (Cramp et al., 1977). Linnman (1983) has speculated that gregarious flocks of migrating shelduck (Tadorna tadorna), whooper swans (Cygnus cygnus), bean geese (Anser fabilis) and greylag geese (A. anser) may cause seasonal influxes of allochthonous materials to lakes around the Swedish coast, thus accelerating eutrophication. However, much of this food comes from around the margins of the water body or from within the watershed and therefore will be of less consequence than food imported from outwith the vicinity.

In view of their social organization, roosting and feeding behaviour, gulls are probably the most important species with respect to influencing trophic state of lakes and reservoirs.

The increase in numbers and spread of Larus spp., principally black-headed, common and herring gulls, which has been widely observed in much of Europe, has been well documented, although the exact reasons remain unclear: increases in the numbers of man-made water bodies (reservoirs, fishponds) and in the availability of food (urban rubbish tips), as well as overcrowding of older roosting/feeding stations have all been suggested (Hickling, 1977; Cramp et al., 1983). Freshwater lentic sites close to urban rubbish tips (Hickling, 1977) or to busy tourist routes, where food at lay-byes is readily available (Jenkins and Bell, 1985), are amongst favoured roost sites for black-headed and herring gulls. Roosting colonies of 10 000 birds are fairly common, and colonies as large as 100 000 are known (e.g., Draycote Water, Warwickshire, UK, Hickling, 1977).

Assessments of the effects of roosting gull populations on nutrient inputs to water bodies have been made by a number of authors (Leentvaar, 1967; McColl and Burger, 1976; Gould, 1977; Gould and Fletcher, 1978; Beveridge, Beveridge and Muir, 1982) and increases in pH, conductivity, organic matter, BOD, nitrogen, phosphorus, coliform bacteria and plankton have all been reported. In terms of trophic state, nitrogen and phosphorus inputs are undoubtedly the most important determinants (OECD, 1982). The daily nitrogen and phosphorus production for a number of species is summarized in Table 11. Unfortunately, the figures for nitorgen loadings are likely to be much higher than shown, as difficulties were experienced in increasing the oxidized inorganic nitrogen components (Gould, 1977).

Annual loadings of nutrients at a site can be estimated using the values in Table 11 and data on colony size, and by invoking assumptions of the duration of foraging gut transit time, distance between feeding ground and roost site, length of time spent at the roost site each day, and the number of days each year that the colony spends at the roost site. Using available published data for a number of water bodies in the UK, areal loadings from roosting gull colonies have been estimated (Table 12). If we assume that the mean depths of these water bodies are between 10 and 20 m (there are no readily available data), and compare the estimated loadings with Vollenweider's (1968) boundary values for oligotrophic and eutrophic lakes, we find that the loadings from birds alone at Draycote Water are sufficient to induce eutrophy, although those for the other two water bodies are likely to be much less significant.

Table 11

Estimated 24-hour nutrient loads (mg) for our species of gull (modified from Gould, 1977; Gould and Fletcher, 1978)

Species	NH_3	Kj.N	Org.N	Sol.P	Tot.P.
Herring gull	402	1 819	1 416	92	115
Black-headed gull	211	919	708	47	58
Lesser black-headed gull	134	829	689	42	50
Common gull	113	608	495	30	38

<u>Table 12</u>

Estimated[1/] annual areal loadings of nitrogen and total phosphorous compounds for several UK lakes and reservoirs. Data from Hickling (1977), Benton et al. (1983), Jenkins and Bell (1985), Benton and Khan (pers. comm.), and Sibly (pers. comm.)

Site	Location	Size (ha)	Colony size	Species	P loading ($gm^{-2}y^{-1}$)	W loading ($gm^{-2}y^{-1}$)
Draycote Water	Warwickshire, England	240 (est.)	90 000 (1973)	Black-headed (60 000) Herring (30 000)	0.15	4.78
Loch Kinnard	Deeside, Scotland	95	up to 10 000	Black-headed gulls	0.03	0.81
Mugdock and Craigmaddie Reservoirs	near Glasgow, Scotland	61 (total)	50–420 (1979–86)	Principally herring gulls	0.002	0.083

[1/] Assumes roosting period of 14 hours; one hour flying time each way; 8 hours foraging time; 8 + 6 hours faeces and excretion period. Proportion of waste loadings entering lakes = faeces and excretion period - (foraging time + 1 hour travel time), divided by total faeces and excretion 14 = 0.35; six months of year at site

The conclusions drawn above are supported by studies period = 14 - (8 + 1)/ carried out in the USA by McColl and Burger (1976). They demonstrated that 36% of phosphorus inputs to a shallow pool were due to a migrant breeding population of 30 000 Franklin's gulls (L. pipixcan).

Thus allochthonous inputs of nutrients by roosting gull populations can markedly affect the nutrient states of a water body, although the extent or significance of bird-induced eutrophication in European inland waters is difficult to assess. However, in view of the quantities of waste produced per bird, it is likely to be of only marginal importance at all but a few, densely populated open water sites. Moreover, at carp ponds the effects of waterfowl on productivity and fish yields have, of course, been used to great effect (Woynarovich, 1980).

5. BIRDS AND DISEASE

Birds may affect the incidence of disease among fish populations in a number of ways:

(i) their presence at a water body may be necessary to the completion of a trixenic parasite life cycle which also involves fish;

(ii) they may be responsible for the spread of disease organisms from one fish population to another through migratory/foraging behaviour;

(iii) they may inflict wounds on fish, thus facilitating secondary infection by pathogens, and

(iv) they may stress fish, increasing susceptibility to disease.

Birds can act as final hosts to a number of common metazoan endoparasites of freshwater fish, particularly flukes (Class: Digenea) and tapeworms (Class: Cestoda) (Needham and Wooten, 1978). In Table 13, some of the more common parasites of European freshwater fishes which have birds as their final hosts are listed. The usual final host of fish cestode species appears to be the heron, whilst among fish digenean parasites, herons, gulls, grebes and goosanders are prevalent final hosts.

Some of the parasites listed, such as Diplostomum spathaceum, Ligula intestinalis and Diphyllobothrium spp., have a wide geographical distribution and affect a large number of fish species, whilst others, such as Valipora spp., A. muehlingi and M. yokogawi appear to be more restricted in range and choice of intermediary host species. Moreover, some of the parasites, such as P. cuticola and Tylodelphys spp., have not been reported from fish farmed in land-based (i.e., tank, pond, raceway) systems and appear restricted to open waters and caged fish.

The occurrence of some of the parasites among both wild and farmed fish population can be extremely high. In one study Fuhrmann (1979) found that 40% of one-year old silver carp (Hypophthalmicthys molitrix) stocked in ponds as fry were infected with P. cuticola. In another study McGuigan and Sommerville (1985) conducted a survey of the parasites of caged (Salmo gairdneri) and wild fishes from Loch Fad, Scotland, and found that all roach (Rutilus rutilus) and perch (Perca fluviatilis) and 65% of the feral rainbow trout examined had Diplostomum spp. Amongst the caged fish population, the prevalence of Diplostomum spp. was somewhat lower (30–37%).

Table 13

Common parasites of Europen freshwater fishes which have birds as final hosts

Species	Fish Intermediary	Habitat	Final host	Description	References
(a) Cestodes					
Ligula intestinalis	Cyprinids catastomids	Lakes, reservoirs fishponds	Ardea	Large (up to 20 cm), fleshy plericeroids found in body cavity. Cause compression and distortion of viscera, inhibition of gonadal development, disturbance of behaviour (do not enter spawning shoals, swim poorly)	Arme and Owen, 1968; Hoole and Arme, 1982
Diphyllobothrium dentriticum, D. ditremum, D. latum	Salmonids, coregonids	Lakes, reservoirs	Ardea, man, D. latum	Encyst in viscera and musculature, causing adhesion of viscera, sterility and even death. Long-living stage in fish, hence highest densities found in older fish	Fraser, 1960; Wooten and Smith, 1979; Halvorsen and Andersen, 1984
Valipora campylanaristrota	Cyprinids	Lakes, reservoirs, fishponds	Ardea		Moravec, 1984
(b) Digeneans					
Posthodiplostomum cuticola	Cyprinids	Lakes, reservoirs, fishponds	Ardea, Larus	Metacercariae found in sking, causing black spot disease	Fuhrmann, 1979
Diplostomum spathaceum D. gasterostei	Cyrpinids, salmonids	Lakes, reservoirs, ponds, raceways, tanks	Larus, Gavia stellata	Metacercariae found in the eyes (retina, vitreous humour, lens). Causes cataracts, even blindness, and changes in behaviour	Willomitzer, 1980; Okulewicz, 1984; McGuigan and Sommerville, 1985
Tylodelphus clavata T. prodicipina	Percids, esocids, cyprinids, salmonids	Lakes reservoirs	Podiceps	Metacercariae found in the humour or retina, not in lens	Niewiadomska, 1963; Kennedy and Burrough, 1977
Apophalus muehlingi	Cyprinids	Lakes	Podiceps, Larus	Metacercariae found in the iris	Okulewicz, 1984
Metagonimus yokogawi	Cyprinids	Lakes, reservoirs	Larus, Podiceps, Ardea	Metacercariae occur in the skin	Needham and Wooten, 1978

The effects of the parasites on the fish range from the largely cosmetic to those which influence host mortality. P. cuticola, which causes the unsightly black spot disease in carps, probably has little adverse affect on the host, unless at extremely high densities (Needham and Wooten, 1978). T. clavata is also believed to have little adverse effect on the growth or survivorship of the host fish species (Kennedy, 1984), for although it occurs in the eyes, and sometimes in considerable numbers, it is not found in the lens, and thus probably does not severely affect fish vision.

Some of the parasites listed in Table 13, however, are known to adversely affect their host, causing disruption of behaviour and physiological processes. Heavy infestations of L. intestinalis can severely affect behaviour and cause increased susceptibility to predation, whilst infestation of the eyes by metacercariae of Diplostomum spp., can cause cataracts and blindness which affects behaviour in general, and feeding (Crowden and Broom, 1980) and anti-predator behaviour (Brassard, Rau and Curtis, 1982) in particular.

Few of the parasites listed, however, are known to directly kill their hosts, the exception being D. spathaceum (Brassard, Rau and Curtis, 1982a).

The parasites listed in Table 13 may also cause problems for other reasons. Fish infected by Diplostomum spp. may not take artificial lures, whilst fish with heavy infestations of Diphyllobothrium spp. or L. intestinalis may be repellant to anglers, thus adversely affecting commercial sport fisheries. D. latum, although not as common as other Diphyllobothrium species, is also of concern, since the plericercoids which encyst in the viscera of the fish host are able to pass to man and re-encyst if the fish is eaten raw or is not properly cooked (Meyer, 1970).

Whilst many authors have reviewed the parasite fauna of freshwater fish communities and commented on the possible consequences, there have been few attempts to quantify host mortalities or economic losses. Anderson and Gordon (1982) suggest that by plotting data on parasite burden versus host age, quantitative data on host mortality could be obtained. They suggested that this method was particularly applicable to digeneans. However, their approach was later rejected by Kennedy (1984) who concluded that "the problem of detecting parasite-induced host mortality unambiguously in the field is still unsolved and may be insoluble".

Thus, birds such as herons, gulls and grebes are important final hosts for a number of parasitic organisms, particularly trixenic cestodes and digeneans, which in their larval stages infest both farmed and wild fish populations. Such organisms are dominant among the parasite fauna of many freshwater lakes (Wooten, 1973; McGuigan and Sommerville, 1985), particularly the more eutrophic type, and a number of authors have considered this to be related to the relative abundance of piscivorous aquatic birds and mammals (Esch, 1971; Bayanov, 1980) (see also above).

Trixenic cestode and digenean parasites are often less common among farmed than wild fish, in terms of the range of species reported and in the prevalence and intensities of infection, and it has been suggested that this is due to physical separation of the fish from the snail or crustacean intermediary host (Jurewicz, 1959; Zitnan and Cankovic, 1970; Wooten and Smith, 1980; McGuigan and Sommerville, 1985). In lake-based cages, however, separation from crustacean zooplankton does not occur and thus Diphyllobothrium spp. infestations may be readily transmitted to the caged fish (Matheson, 1979). In land-based farms where cestode and digenean infestations of fish have been reported, these have often originated from the wild fish supplying the unit (Wooten and Smith, 1980).

In conclusion, quantitative evidence for adverse effects on growth, survivorship and economic value of parasites on wild fish populations do not exist and may be impossible to obtain. Whilst evidence for parasite-induced damage to farmed fish may be easier to collect and assess, most of the reports to date tend to be qualitative and anecdotal in nature.

The transfer of potentially pathogenic organisms by birds from one fish population to another has not been well studied. It is known that viruses such as infectious pancreatic necrosis (IPN), viral haemorrhagic septicaemia (VHS) and spring viraemia of carp (SVC) can be isolated from beaks or from regurgitated food several hours after birds had been feeding on infected fish (Olesen and Vestergaard Jorgensen, 1982; Peters and Neukirch, 1986). Orally administered IPN has also been re-isolated from the faeces of birds, even from those produced after several days ingestion (Sonstegard and McDermott, 1972; Eskildsen and Vestergaard Jorgensen, 1973; Peters and Neukirch, 1986). Recently Peters and Neukirch (1986) successfully demonstrated that it was possible to induce an IPN infection in trout fry held in an aquarium (201) after small quantities (0.2 g) of faeces collected from herons which had been feeding on infected fish were dropped in the water.

Whilst it has been shown that birds can act as mechanical vectors of viruses and whilst there is some epidemiological evidence to support the supposition that they can transfer viral diseases on fish farms (Bregnballe, 1981), the importance of birds as vectors of fish viral diseases has yet to be properly assessed.

It has been demonstrated that birds, such as gulls which scavenge on rubbish tips can pick up and disseminate pathogenic micro-organisms such as salmonellae and faecal coliforms (Williams, Richards and Lewis, 1976; Gould, 1977; Gould and Fletcher, 1978; Benton et al., 1983). Increases in bacterial numbers in reservoirs have been correlated with roosting gull numbers (Benton et al., 1983). Whilst some of the bacterial species isolated from bird faeces, such as Edwardsiella tarda, have been implicated in severe outbreaks of septicaemia and enteritis in salmonids (Roberts and Shepherd, 1986), no clear link between bird faecal contamination of water bodies and fish diseases has been established.

The ability of birds to transmit protozoan diseases has been demonstrated by Taylor and Lott (1978). They fed mallards (Anas platyrhynchos) and herons (Nycticorax nycticorax) trout infected with the myxosporodan Myxosoma cerebralis, which causes whirling disease in salmonids, and deposited the faeces in tanks of trout, some of which subsequently developed the disease.

There are a number of metazoan parasites whose larval stages infect fish and whose adult stages occur in birds (see above), and although it seems likely that parasites are transferred from one water body to another by bird hosts, this has neither been demonstrated, nor has its importance as a means of dissemination of parasitic fish diseases been evaluated.

Attacks on fish by piscivorous birds are not always successful (see above) and the resultant wounds may be sufficient to kill the fish directly, act as sites of secondary infection by pathogenic micro-organisms, or result in rejection of the fish for sale. However, there has been little study of the nature of the damage inflicted by birds or assessment of the magnitude of the problem.

Descriptions of characteristic wounds inflicted on farmed rainbow trout by herons and cormorants are given in Ranson (1982) and Ranson and Beveridge (1983). Herons attack from above and cause either scale removal on the sides of the fish by grabbing, or a single puncture wound in the head or back with minimal associated scale removal, as a result of stabbing with the beak closed (see Figure 3). These wounds were observed in both pond and caged fishes. Cormorant attacks on caged fish resulted in a puncture mark with some associated scale loss on one side of the fish, and an area of scale removal on the opposite side (Figure 3). There are no descriptions of wounds inflicted on fish by other avian species.

Studies of fishing in rivers by herons have shown that the rate of injury is positively correlated with the quantities of fish successfully captured (Geiger, 1984). However, this differs from the farmed situation. In studies of nocturnal feeding by herons at carp ponds, Draulans and van Vessem (1985) showed that the success rate of attacks was low (<70%) on arrival, increased to a maximum (92%) 6–10 minutes after arrival and thereafter declined. Catch rate was also negatively correlated with flock size.

Studies on fish predation by cormorants at carp ponds have shown that the success rate of capture of larger fish (550–700 g) is much lower than that of smaller individuals, and that fish of up to 700 g can be severely damaged (Moerbeek et al., 1987).

It must be borne in mind that not all failed attacks result in wounding: the proportion of failed attacks that do result in damage will depend on size/age and species involved, as well as the nature of the environment (e.g., farmed/open waters; cage/pond). For example, Ranson and Beveridge (1983) concluded that few, if any, attacks by herons and cormorants on caged fish were likely to be successful, whereas those on fish reared in ponds or raceways certainly are.

There are no published data on the extent of bird-induced wounding amongst fishes of open waters. Estimates from one cage rainbow trout farm on the west coast of Scotland, which was visited by both herons and cormorants, showed that on average 2.2% of all live fish examined had been wounded by birds, although the proportion varied with time of year, size, duration of time the fish had spent on the farm and mesh size (Ranson, 1982). In a study of trout ponds visited by herons, less than 2% of fish showed signs of having been attacked (Meyer, 1980; 1981).

There have been few estimates of economic losses caused by wounding, although Meyer (1980) has discussed the proportion of fish rejected for sale on these grounds (see above). Neither the effects of scale loss nor the invasion of wound sites by pathogenic organisms have been studied. From observations on cage rainbow trout farms, however, it was observed that more than 4% of dead fish retrieved by staff from cages had bird-inflicted wounds (2% of healthy stock, see above) suggesting that wounded fish were almost twice as likely to die as individuals which had not been physically damaged (Ranson, 1982).

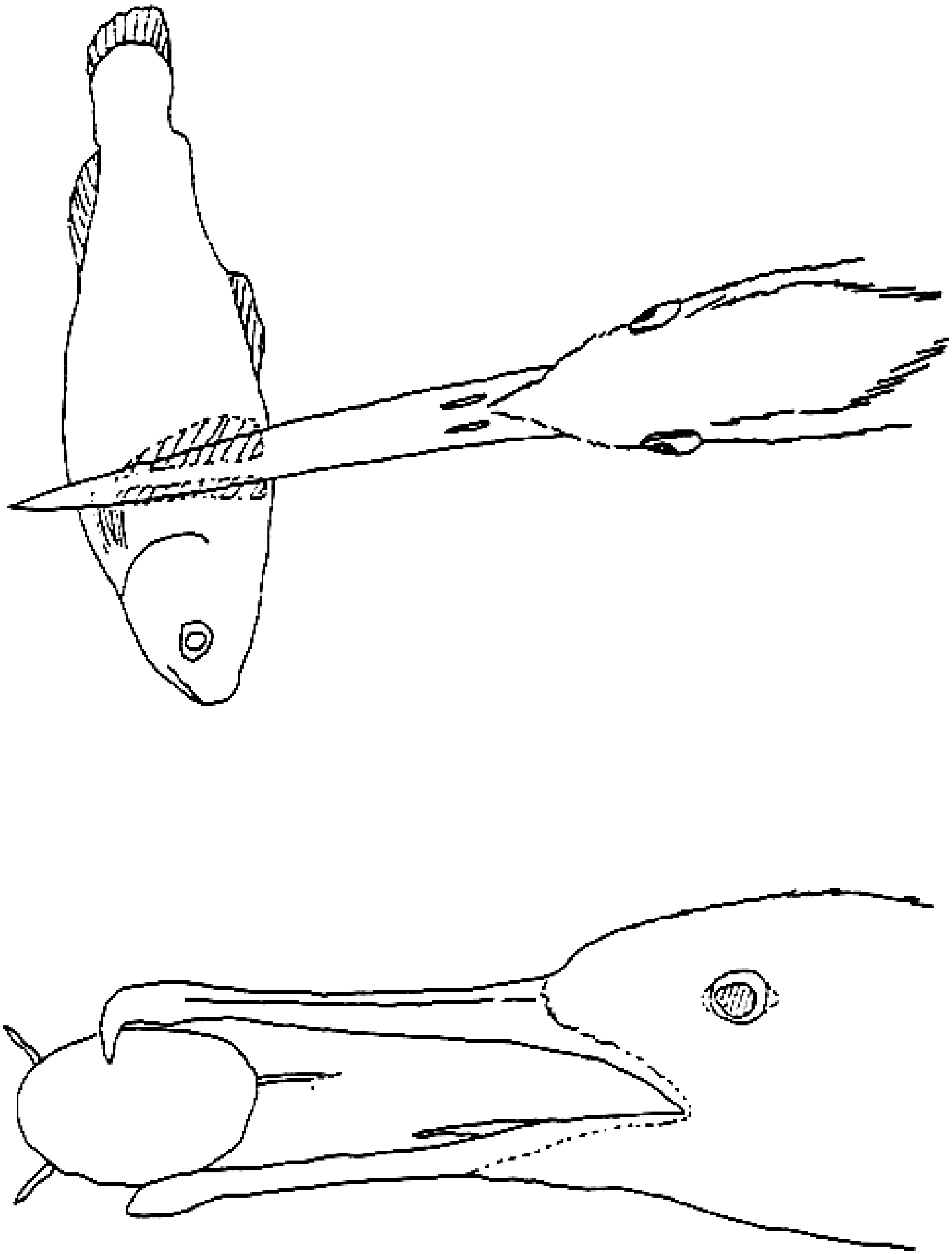

Figure 3 Sketch showing damage inflicted by herons and cormorants. Shaded area indicates scale removal (from Ranson and Beveridge, 1983)

It has been demonstrated under laboratory conditions that the presence of piscivorous birds can disrupt the normal swimming and foraging behaviour of fish (Milinski and Heller, 1978; Giles, 1983), although this has not yet been studied in wild or farmed fish populations (see above). Physiology-based studies of stress in fish caused by birds have also yet to be carried out.

6. CONTROL OF BIRD-RELATED PROBLEMS

Approaches to alleviating problems caused by birds at inland water fisheries, hatcheries and fish farms, fall into two broad categories; prevention and cure. Prevention of bird problems can be achieved through careful site selection, but, of course it is an option which is only open to hatcheries and farms, unless, perhaps, reservoirs are included. However, economic and logistic considerations in reservoir siting will far outweigh any foreseeable problems that may be caused by birds, and so remedial measures are likely to be the only option available to managers of open waters.

Preventative measures have been recommended as a means of forestalling bird problems in the USA. Lagler (1939) and Salyer and Lagler (1946) noted that the incidence of kingfisher predation was much greater at hatcheries built on or close to the Great Lakes than those sited further inland, and suggested that fish culture establishments should be located away from the major migration routes or flyways of fish-eating birds, and outside the flight range of large nesting or roosting colonies. Similar advice has more recently been propounded by the US Fish and Wildlife Service and Department of the Interior (Salmon and Conte, 1982).

Whilst it sometimes may be possible to follow such advice, there are very likely to be over-riding economic considerations why this may not be practicable. Moreover, some species, such as the heron, can fly considerable distances in order to forage for food (Marion, 1984), and colonies are so common, that in part of Europe it may just not be possible to avoid them. There are also difficulties posed by species such as the cormorant and the black-headed gull, which are greatly extending their ranges in Europe (Cramp et al., 1977; 1983; Hansen, 1984; Im and Hafner, 1984). For example, the pond-based farm at Lelystad, the Netherlands, which was completed in 1963, had no problems with cormorant predation until a colony became established in nearby IJsselmeer in 1978 (Moerbeek et al., 1987).

A number of methods for reducing existing problems caused by birds have been proposed and/or evaluated, ranging from attempts to remove or dissuade visiting birds to reducing the vulnerability of fish to attack.

The shooting of birds visiting fish farms or lakes was once an almost universally practiced panacea (see Lagler, 1939; Mott, 1976; Dombeck, Hammill and Bullon, 1984, for reviews). Today the majority of bird species are protected by law in most, although not all (see below), parts of North America and Europe, and whilst this has had an undoubted effect on reducing the incidence of birds shot, shooting is still resorted to by many fish farmers. For example, although the heron is protected by law in England, Meyer (1981) estimates that some 3 600–5 000 birds are shot each year on fish farms, representing a significant proportion of the British population (estimated at around 5 400 breeding pairs in the late 1970s). In some parts of Europe, such as Scotland and Denmark, herons may be shot quite legally (Mills, 1979; Moller and Olesen, 1984), albeit that a licence may be required. In Denmark it is estimated that approximately 8% of the heron population are killed each year at fish farms (Moller and Olesen, 1984).

The reasons for the appeal of shooting as a method of control are patently obvious: it is an immediate and apparently effective response to a perceived problem which probably engenders a feeling of satisfaction in the perpetrator. However, numerous studies have shown that the efficacy of shooting is dubious, being either totally ineffective, or resulting in only temporary remission. It is also costly.

Researchers in North America have shown that it is possible to control, or even eliminate, goosander populations by shooting and that this can cause a marked improvement in fish catches (White, 1939; Huntsman, 1941; Elson, 1962; Smith, 1968; Erskine, 1972). However, Elson's studies showed that goosander numbers had to be reduced to around one-third of the initial density, involving massive investments in manpower, before shooting proved effective, whilst Smith's eradication of birds programme was carried out simultaneously with a lake fertilization programme and the extermination of piscivorous mammals, making it difficult to evaluate the effectiveness of the avian control component.

Studies in the UK, Germany and Belgium have all shown that shooting of herons has little real impact on the number of fish taken, as immigration of replacement birds rapidly takes place (Meyer, 1980, 1981, 1982; Ranson and Beveridge, 1983; Utschick, 1983; van Vessem, Draulans and de Bont, 1985). Moreover, as Draulans and van Vessem (1985) have demonstrated, the intensity of predation is greatest in the first few minutes after landing at the ponds and rapidly decreased with time, and so birds would have to be shot as soon as possible after arrival in order to effectively reduce the quantity of fish taken. They also showed that success in prey capture was significantly higher among small groups of feeding birds, thus negating the effects of shooting, in part at least (see above).

Other methods for removal of birds, such as trapping, poisoning and capture and release have all been tried, usually with similar results to shooting. Van Vesem, Draulans and de Bont (1985) tried releasing herons 30–150 km from the site of capture. Although none of the adults reappeared, many of the juveniles were observed back at the farm within one month.

A large number of bird scaring devices, including both audio and visual deterrents, sometimes in combination, have been tried with mixed success. Audio deterrents include loud noises (gun-shots, humlines, automatic gas canons, fireworks) taped human voices and distress or alarm calls. Certain types of noise, such as those caused by passing vehicles, have been shown to be ineffective in reducing bird numbers (Draulans and van Vessem, 1985). Lagler (1939), Salyer and Lagler (1946) and Spanier (1979, 1980) have shown that loud noises are only temporarily effective in deterring visiting birds, whilst Hewitt (1936) and Moerbeek et al., (1987) claim that they are useless. In a recent review, Salmon and Conte (1982) state that most loud noise scaring devices are of limited value and stress the importance of choosing automatic equipment which emits noises at irregular intervals and whose position or direction of sound emission can be changed frequently.

The use of loud noise scarers is not recommended if the site is close to human habitation or if there are livestock or game animals in the vicinity (Salmon and Conte, 1982; Im and Hafner, 1984). Salmon and Conte also state that loud noises can disturb spawning catfish.

Taped alarm or distress calls have been successfully used to deter a variety of visiting birds from open waters (Benton et al., 1983; Shedden, 1983) and fishponds (Spanier, 1979; Salmon and Conte, 1982; Utschick, 1983). Reaction varied with species, location, size of area and time of year, and experience has shown that this method is probably most effective if the calls are broadcast as the birds begin to arrive. Salmon and Conte (1982) state that birds soon become used to these calls. However, whilst Utschick's (1983) study of herons corroborates their views, studies of gulls and night herons have shown this method to be effective over many months or even years (Spanier, 1979, 1980; Benton et al., 1983; Shedden, 1983).

A wide range of visual deterrents, including foil and cloth strips, flags, balloons, flashing lights, model aircraft, scarecrows and model raptors have been used. Again, results have been variable, depending upon species, time of year and location (Lagler, 1939; Salyer and Lagler, 1946; Meyer, 1981; Salmon and Conte, 1982; Utschick, 1983).

In conclusion, the effectiveness of most visual and many audio deterrents is questionable. Greater success has been achieved with some species, such as gulls, than others (e.g., cormorants) and it is important that equipment is mobile and that audio emissions are varied in direction and given at irregular intervals. A number of studies have shown that large flocks return more quickly after disturbance than small flocks and that it is more difficult to deter birds if there are no alternative feeding or roost sites nearby (Ranftl and zur Muhlen, 1977; Draulans and van Vessem, 1985). It is also more difficult to deter piscivorous species if the ponds are heavily stocked (Utschick, 1983; Barlow and Bock, 1984). A combination of the above deterrent techniques is probably more effective than reliance on any single strategy. Other deterrents which have been less frequently tested include water spray systems and electrically charged wires. The former has proved particularly effective against gulls roosting on reservoirs in North America, whilst the latter has been shown to be largely ineffective (Emigh, 1962, in Mott, 1976; Salmon and Conte, 1982).

There are a number of methods available for reducing vulnerability to attack by piscivorous birds. The most commonly employed involves the construction of some kind of physical barrier. The complete enclosure of some aquaculture facilities by netting or mesh has been shown to be very effective in eliminating predation by all types of piscivorous birds. In order to protect caged stock, 5–10 cm mesh top nets must be firmly secured to the cages and curtains of similar sized mesh must be hung around the cages (Ranson, 1982; Ranson and Beveridge, 1983; Beveridge, 1987). The anti-predator net curtain must be hung at least 30–40 cm distance from the cage bag and should extend for several metres below the cage floor. Even then, damage by diving birds can still occur (Ranson, 1982). Moreover, anti-predator nets are expensive, reduce current flow through cages and add to management problems, as well as trapping and killing occasional birds.

Tanks and small raceways can be effectively and inexpensively protected by covering with netting or chicken mesh (Hewitt, 1936; Lagler, 1939; Mott, 1978; Salmon and Conte, 1982; Martin, 1982). Mesh size must be related to the size of the piscivore and the mesh or netting should be attached to a wooden or pipework frame so that it can be readily removed to facilitate routine operations.

Small ponds, densely stocked with valuable fry or fingerlings, may be cost-effectively protected by entirely enclosing in netting, or wire or plastic mesh, supported by a wooden or metal framework of posts and beams. The resultant cage can be entered through a screened gate and should be high enough to allow staff to work without discomfort. Such caging is compulsory at Danish fish farms (Meyer, 1981).

Where large ponds or open waters must be protected, partial enclosure using overhead wires or lines is less expensive and is much more practicable than complete enclosure. Wire, braided, mono- and multi-filament man-made fibres are commonly used. Choice of material and system of enclosure should be based upon cost, expected duration of damage, size of facility, extent and nature of predation, management, location and aesthetics. Various paterns of l iens have been tried: parallel, grid, irregular and radial. However, few experiments have been tried to determine the most cost-effective system. Moerbeek et al. (1987) found no significant differences in effectiveness between a regular grid pattern, irregularly placed lines, or a radial pattern of lines.

The distances between lines should be determined by species. According to Salmon and Conte (1982) 120 cm spacings are effective in deterring gulls, 60 cm spacings should be used against goosanders and 30 cm for herons. Moerbeek et al. (1987) found that 20 m spacings were as effective as 10 m spacings in deterring cormorants. The recommended height of the lines above the water is 40–60 cm (Lagler, 1939; Moerbeek et al., 1987).

Partial screening suffers from a number of disadvantages. It is useless against very small birds, such as kingfishers (Salmon and Conte, 1982) and is only partly effective against other species. Moerbeek et al. (1987) showed that only 5–11% of cormorants visiting their fish farm left without landing as a result of the lines, and that few of the birds encountered problems either during landing or take off, irrespective of the system of lines used. Although Im and Hafner's (1984) study of cormorant predation in the Camargue showed that a system of lines was successful in repelling most visiting birds, it was not made clear whether there werer unprotected ponds with attractive stock close by.

Partial screening has high associated maintenance costs and can make routine operations around the farm difficult, particularly if lines have been laid out at the ends of the system in order to prevent wading birds from simply walking in under the wires. This type of screening is also considered by many as unsightly and is not practicable for protecting large open areas of water.

If wading birds are the principal problem species, then extremely simple systems may be employed to protect farm stock. Lagler (1939) suggested that marginal chicken wire fences, 60 cm high, would be sufficient to protect raceways against predators. More recently, Meyer (1980, 1981, 1982) has claimed that a single or double cord fence, 25–35 cm high, in combination with a floatline laid around the margins is an inexpensive and effective method of protecting pond stocks against herons. A similar system has been suggested by Salmon and Conte (1982).

Alternative methods of reducing the vulnerability of valuable stock to avian predators have involved the introduction of a buffer population of fish, either by mixing smaller fishes with more valuable larger ones, or by introducing a low value, easily caught species, such as the mosquito fish (Gambusia affinis) (Lagler, 1939; Utschick, 1983; Barlow and Bock, 1984). Lagler (1939) also suggested building small ponds close to the fish culture ponds and stocking them with frogs and toads.

Fraser (1974) attempted to reduce the vulnerability of brook trout to predation by training hatchery reared fishes to avoid an electrified model bird moving through the water in the hatchery raceway. Low survivorship rates of released fish suggest that the training was of little value.

Finally, it has been suggested that predation by birds can be reduced by modifying the ways in which farms are designed and managed. It is argued that tank, raceways or cage systems are much less vulnerable and easy to protect than large earth ponds (Salmon and Conte, 1982; Beveridge, 1987). Deeper ponds (1 m) with steep-sided banks have been shown to deter waders such as herons (Meyer, 1980, 1981, 1982). However, deep ponds may not be cost-effective and steep banks are prone to erosion, although this can be reduced by compaction with heavy clay. Banks and levees should be cleared of vegetation which may be used as cover, and any facility that can possibly be used as a perch removed (Cottam and Uhler, 1936). Salmon and Conte (1982) recommend that raceways with vertical walls rising at least 1 m above the water surface will prevent many species from taking fish.

Good management practices can help. Feed bags should not be left outside and dead fish should be removed and carefully disposed of (Beveridge, 1987). All screens and netting on cages, tanks and raceways must be secured and maintained in good order. Changes in management practices may also be beneficial. It has been suggested that valuable or vulnerable fishes should be stocked in ponds close to farm office buildings, as proximity to man will deter many species (Salmon and Conte, 1982; Moerbeek et al., 1987). Encouraging the public on to the farm to fish in the ponds may serve not only as an added source of revenue, but may also help keep birds away.

Reductions in stocking density, although not always practicable, can minimize the incidence of predation (Barlow and Bock, 1984). Changes in the timing of stocking may be more effective. Moerbeek et al. (1987) suggest delaying transplanting carp fry from the hatchery to open ponds until late June. As a result, not only will the period when they are vulnerable to predation be shorter, but the number of visiting cormorants should also be greatly reduced. In Canada, Mace (1983) reduced the incidence of predation by gulls on hatchery-reared juvenile salmonids to 5–15% by delaying the release until most of the predatory migrating birds had disappeared, restricting the release to tides and times of day when the birds were least effective at feeding, and by decreasing the duration of the release period in order to minimize the accumulation of predators.

In conclusion, a number of preventative and ameliorative measures are available to fisheries managers and fish farmers for reducing problems associated with birds. However, few options other than the complete enclosure of stock are likely to be completely effective, and a combination of strategies is likely to be superior to reliance on any single measure. The cost-effectiveness of any measures should be carefully considered.

Changes in public attitudes and in the law means that killing or maiming as a means of reducing problems is now unacceptable. Indeed, conservation of many bird species traditionally viewed as enemies by fishermen and fishfarmers is of increasing importance as there is growing public interest in their aesthetic and recreational value (Cottam and Uhler, 1936; Mott, 1978; Dombeck, Hammill and Bullon, 1984). In the USA, the Fisheries and Wildlife Service has recently instigated a research programme into making fish-eating birds and fish rearing more compatible. In the UK, Mills (1979) reports that one fish farmer has turned an apparent problem into profit by encouraging the public to visit his farm to view a rare pair of ospreys fish trout from the ponds.

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ANNEX 1

Report of the Twelfth Session of EIFAC, Budapest, Hungary, 1982

(a) Prevention and control of bird predation in aquaculture and fisheries operations

69. This point raised by the delegation of the Netherlands appeared to be of considerable interest to many delegations. It was decided to take the following action:

- a questionnaire on the direct and indirect economical impact of bird predation both in different types of aquacultural enterprises, as well as in open-water fisheries, will be prepared by Dr C.M. Bungenberg de Jong (the Netherlands) and the Chairman of Sub-Commission II. This questionnaire will be circulated by the EIFAC Secretariat;
- a working party was established to prepare a document based on literature and experimental data concerning bird damage in:

    (i) pond fish culture;

    (ii) trout culture, and

    (iii) open waters

  taking into account related aspects of fish diseases. Dr Bungenberg de Jong agreed to convene this Working Group. Dr Molnar (Hungary) as well as two other Working Group members, to be appointed respectively by the delegations of Denmark and France, will assist in the preparation of such a manuscript, and
- the above-mentioned documents (the replies to the questionnaire and the Working Group document, respectively) will be combined by the Secretariat to be handed over to the Director-General of FAO for further appropriate action.

Report of the Thirteenth Session of EIFAC, Aarhus, Denmark, 1984

G. Prevention and Control of Bird Predation

84. A Working Party has been established under the leadership of Dr C.M. Bungenberg de Jong (the Netherlands), following the proposal made at the Twelfth Session for the study of the prevention and control of bird predation in aquaculture and fisheries operations.

85. A questionnaire on the economical impact of bird predation has been distributed to Member States, but only eight countries have provided answers to date. A repliminary analysis of these has been presented to the Sub-Commission but further data is still needed to complete such analysis.

86. It was recommended that the National Correspondents be informed that the deadline for sending the questionnaire back has been extended until 30 November 1984. A strong plea was made for a stronger cooperation to enable the Working Party to successively terminate this part of its mandate. It was also agreed that a final draft be prepared as soon as possible and circulated to Member States for approval, prior to final publication.

87. A review of the literature on this subject will then be prepared by the Working Party with the assistance of Dr M. Beveridge, University of Stirling (UK), to be also finalized as soon as possible.

Report of the Fourteenth Session of EIFAC, Bordeaux, France, 1986

G. Prevention and Control of Bird Predation

78. The Convenor of the Working Party, Dr C.M. Bungenberg de Jong (the Netherlands) reported on the present status of the work. The final draft will be ready shortly and circulated to the EIFAC National Correspondents for approval, prior to publication as an EIFAC Technical Paper. This document will include a literature review.

ANNEX 2

QUESTIONNAIRE

A. POND FISH CULTURE

1. General Information

- Total area of fishponds
- Total production (specified to fish species, weight and monetary value)
- Number of fish farms

2. Bird Problems

Does there occur (locally) a serious waterbird problem, hampering fish production. If yes, which problems are encountered (predation, interference with artificial feeding, spread of fish diseases, disturbance during wintering, etc.)

3. Predation

Enumeration of fish-eating bird species in order of importance (English/French and scientific Latin names). For each single bird species the season in which damage is caused and the status of the species in this season (breeding bird, migrant or winter visitor) should be mentioned.

- On which fish species (size interval, weight classes) does predation mainly take place;
- Which ponds are most vulnerable to predation (size, vegetation on banks, water depth, turbidity).

4. Interference with Artificial Feeding

- Do birds interfere with artificial feeding
- Which bird species compete in this respect
- Under which circumstances (feeding places, automatic feeders) and by offering which kind of food (grains, pellets) most damage is caused.

5. Fish Diseases and other Problems

- Do birds cause damage by spreading diseases
- If yes, which diseases are spread by which bird species
- Do predatory birds stress the pond fishes and force them to hide, resulting in a lower growth or mass starvation
- Do birds disturb fishes in wintering ponds

6. Measures

- Which preventive of repressive measures have been taken to control damage caused by birds
- Which measures have proved to be successful
- Which measures have appeared to be not effective, specially by repeated use

7. Legal Position

- Which of the above-mentioned bird species are protected by law, either during the whole year or part of the year

- Are these bird species also legally protected on fish farms.
- If yes, are special licences granted in case of serious damage on fish farms.

8. <u>Indemnification</u>

- In case of protected birds, does there exists a (legal) settlement of damages
- Who is paying the compensation
- Are subventions granted to take preventive measures on fish farms

9. <u>Research</u>

- Is research being or has research been done on the kind and extend of the bird problem on fish farms
- Have investigations been made concerning the most effective techniques preventing bird damage
- Are there publications in this field

10. <u>Economical Impact</u>

- Can the direct of indirect damage, caused by birds on fish farms, be expressed in terms of monetary value (US$)
- If not known, can the economical impact be estimated using other parameters as percentage lack of production or percentage additional losses due to birds.

B. TROUT CULTURE

1. <u>General Information</u>

Total area of production ponds and other facilities (race ways, cage culture). Total production per year in tons for each trout species (English/French and scientific Latin names). Number of trout farms.

2. <u>Bird Problems</u>

Does there occur bird problems.

3. <u>Protection Against Birds</u>

Are any measures taken to protect against birds. If yes, which measures are taken. Which measures are effective and which measures are not. If there are measures, could you then give data (if they exist) from before measures were taken, for comparison.

4. <u>Predation</u>

Enumeration of fish-eating bird species (English/French and scientific Latin names) in order of importance. On which size does predation take place.

5. <u>Diseases</u>

Which diseases are spread.

6. <u>Legal Position</u>

Which of the bird species are protected, and for what period. Are some of them protected outside, but not on the trout farm.

7. <u>Research</u>

What research has been done on the bird problems (e.g., publication).

8. <u>Economical Impact</u>

Is it possible to give a guess on the damage caused by birds. Does the trout farmer get compensation for the damages.

C. OPEN WATERS

1. General Information

- Total area of open water, specified to lakes, reservoirs, rivers, etc.
- Total annual catch (open water fisheries), specified to fish species
- Total number of professional fishermen
- Total number of sport fishermen

2. Bird Problems

Are there known problems caused by water birds, hampering commercial fisheries in open water. If yes, which problems are encountered.

3. Predation

Enumeration of fish-eating bird species in order of importance (English/French and scientific Latin names). For each single bird species the season in which damage is caused and the status of the species in this season (breeding bird, migrant or winter visitor) should be mentioned.

- On which fish species (size interval, weight classes) does predation mainly take place and in which season (including restocked fishes)
- Which habitats are most vulnerable to predation (size, water depth, vegetation on banks, turbidity).

4. Fish Diseases

- Do birds cause damage in open waters by spreading fish diseases
- Do birds eat preferentially sick or dead fishes
- Do birds disturb fishes causing injuries, resulting in starvation of decreasing economical value

5. Bird Predator Populations

- Which of the above-mentioned bird-species are protected by law, either during the whole year or part of the year
- Is the presence of bird-predators recent, old, immemorial, stable, increasing, dropping, during the whole year or part of the year (resident or migrating birds)
- Can this tendancy be relied to legal position of species
- Is the presence of birds limited to a strict habitat or not; which habitats are the most used (season); relation with local bird refuges
- Is there a modification on size, i.e., numbers of fish populations due to bird predation
- Are there other possible causes (pollution, modification of habitat).

6. Measures

- Which preventive of repressive measures have been taken to control damage caused by birds
- Which measures have proved to be successful
- Which measures have appeared to be not effective, specially by repeated use

7. Research

- Is the population dynamic of bird predators studied (are natural regulation factors known)
- Is research being or has research been done on the kind and extend of the bird problem on open waters.
- Have investigations been made concerning the most effective techniques preventing bird damage
- Are there publications in this field

8. Economical Impact

- Can the direct or indirect damage, caused by birds on fish farms, be expressed in terms of monetary value (US$)
- If it is not known, can the economical impact be estimated using other parameters as percentage lack of production or percentage additional losses due to birds.