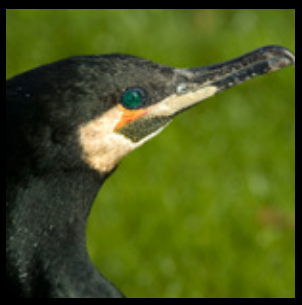
The INTERCAFE Cormorant Management Toolbox

Methods for reducing Cormorant problems at European fisheries



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This publication has been produced by **INTERCAFE's** Work Group 2, the 'Conflict Resolution and Management' group, which comprised 22 researchers from 17 countries across Europe and beyond (for details of WG2 participants, please see Appendix).

This publication was drafted by Ian Russell, Bruno Broughton and Thomas Keller with substantial editorial input and help from Dave Carss. Specific sections of text, figures and Case Studies were provided by: Michal Adamec, Thomas Bregnballe, Henri Engström, Marijan Govedic, Miha Janc, Verena Keller, Manos Koutrakis, Loïc Marion, Petr Musil, Simon Nemtzov, Erik Petersson, Henrik Lykke Sørensen, Tamir Strod, Stefano Volponi and Ian Winfield. Helpful comments and corrections on various drafts were provided by the above and also by: Zeev Arad, Timo Asanti, Redik Eschbaum, Robert Gwiazda, Reinhard Haunschmid, Scott Jones, Botond Kiss, Vilju Lilleleht, Oleg Nemenonok, Kareen Seiche and Josef Trauttmansdorff. A number of people also kindly provided photographs for inclusion and individual sources are acknowledged under each picture.

During the drafting process, the **Toolbox** was reviewed by the Work Group and was also made available to all **INTERCAFE** participants for comment and correction. Numerous participants from **INTERCAFE's** other two Work Groups made presentations and contributions to the Conflict Resolution and Management group meetings, and these meetings were also informed on occasions by discussions with invited experts and local stakeholders. Wherever appropriate, information from these sources has also been incorporated into the Toolbox.

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1 PREFACE

This publication is supported by **COST**. It is one of the outputs of the **INTERCAFE COST** Action (635). **COST** (European Cooperation in Science and Technology) is the longest-running intergovernmental network for cooperation in research across Europe.

INTERCAFE — 'Conserving biodiversity: interdisciplinary initiative to reduce pan-European cormorant-fishery conflicts' — was awarded funding for four years (2004–2008). **COST** Actions are charged with directing European science and do not pay for researchers' time. Instead, funding was available for **INTERCAFE** to organise and run a series of international meetings, drawing together researchers from a number of disciplines (bird-related and broader ecology, fisheries science and management, sociology, social anthropology and international law) and other experts (very often connected with fisheries production, harvest and management, or to regional/national policy and decision-making). Under **INTERCAFE's** coordination, interested parties, from local stakeholders to international policy-makers, were thus offered a unique opportunity to address European cormorant-fisheries issues.

The main objective of **INTERCAFE** was to improve European scientific knowledge of cormorant-fisheries interactions in the context of the interdisciplinary management of human-wildlife conflicts at local to international levels across Europe. It also aimed at delivering a coordinated information exchange system and improved communication between stakeholders. To this end, **INTERCAFE** attempted to address:

i. the fundamental distrust between the main stakeholder groups which was compounded by the disparate and uncoordinated nature of available sources of information;
ii. the necessity of applying an integrated interdisciplinary research approach (biological, social, legal) to cormorant-fishery conflicts (as these are as much a matter of human interests as they are of biology or ecology), thus recognising the need for different perspectives in the development of collaborative strategies, and
iii. the lack of an integrated understanding of the interdisciplinary factors at the heart of cormorant-fisheries conflicts that precludes the provision of useful and practical information and advice to all interested/affected parties.

The **INTERCAFE** network comprised almost seventy researchers from 24 EU Member States (all except Luxemburg, Malta and Spain) and other countries in continental Europe (Georgia, Norway, Serbia) and the Middle East (Israel). In addition to these 28 countries, Ukraine and Croatia were also associated with the Action. **INTERCAFE** held a series of eight meetings, each themed around a topic particularly relevant to the host country:

1. Gdansk, Poland, April 2005 — *'Cormorant ecology, commercial fishing and stakeholder interaction'*
2. Saxony, Germany, September 2005 — *'Commercial carp aquaculture'*
3. Hula Valley, Israel, January 2006 — *'Cormorant-fishery conflict management in the Hula Valley, Israel'*
4. Bohinj, Slovenia, October 2006 — *'Angling and EU legislation'*
5. Hanko, Finland, April 2007 — *'What to do when the cormorant comes'*
6. Po Delta, Italy, September 2007 — *'Extensive aquaculture systems and relationships between stakeholder perspectives and different spatial and institutional levels'*
7. South Bohemia, Czech Republic, April 2008 — *'Management practices in a complex habitat mosaic and at local, regional and national levels'*
8. Paris, France, September 2008 — *'The management of cormorant-fisheries conflicts in France and the wider European context'*

At each meeting, **INTERCAFE** participants worked in one of three Work Groups, covering the broad aims of the Action:

- Work Group One — Ecological Databases and Analyses
- Work Group Two — Conflict Resolution and Management
- Work Group Three — Linking Science with Policy and Best Practice

Most meetings included a field visit to allow participants to see cormorant-fishery conflicts at first-hand. In addition, wherever possible the **INTERCAFE** budget was also used to invite appropriate local, regional, national or international experts to these meetings. Through these discussions and interactions, **INTERCAFE** participants tried to understand the diverse cormorant-fishery conflicts in Europe and beyond.

This publication is one of a series of **INTERCAFE** outputs aimed at providing readers with an overview of European cormorant-fishery conflicts and associated issues, which is as comprehensive as possible given the budgetary and time constraints on all of **INTERCAFE's** participants.

The **INTERCAFE** publications are:

- Cormorants and the European Environment: exploring cormorant status and distribution on a continental scale. (ISBN 978-1-906698-07-2)
- The **INTERCAFE** Field Manual: research methods for cormorants, fishes, and the interactions between them. (ISBN 978-1-906698-08-9)
- The **INTERCAFE** European Cormorant Management Toolbox: methods for reducing cormorant problems at European fisheries. (ISBN 978-1-906698-09-6)
- Cormorant-fisheries conflicts at Carp ponds in Europe and Israel: an **INTERCAFE** overview. (ISBN 978-1-906698-10-2)
- Essential social, cultural and legal perspectives on cormorant-fisheries conflicts. (ISBN 978-1-906698-11-9)

Highlights from these publications are available in **INTERCAFE**: an Integrated synthesis (ISBN 978-1-906698-06-5) and also from http://www.intercafeproject.net

Drawing on **INTERCAFE's** privileged opportunity to see and hear about cormorant-fishery issues across Europe and beyond, the **INTERCAFE** European Cormorant Management Toolbox aims to explore the diverse range of mitigation techniques currently available. It is hoped that this exchange of information will help to reduce cormorant-fishery interactions where cormorant predation is a concern. The Toolbox is intended to provide fishery managers and owners with the basis to experiment and devise specific mitigation techniques or programmes tailored to suit their individual needs.

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2 INTRODUCTION

Large increases in Great Cormorant (*Phalacrocorax carbo*) populations have occurred across Europe over the past 30–40 years, and this has resulted in widespread conflicts with commercial and recreational fishery interests in freshwater, estuarine and coastal habitats. Indeed, the pan-European increase in Great Cormorant numbers is mirrored by equally dramatic rises in other parts of the world, such as the increase in numbers of the Double-crested Cormorant (*Phalacrocorax auritus*) in North America. Although cormorant biology and ecology have been the subject of considerable scientific research, understanding the interactions between cormorants and fish and fisheries has remained problematic. This is inevitable given the inherent difficulties in obtaining sound, quantitative information on fish stocks, particularly in large bodies of water. The consensus of scientific opinion on why cormorant numbers have risen so quickly centres on a few key factors, namely:

- more stringent controls, or prohibition, of indiscriminate shooting, as well as enhanced protection afforded to cormorants and cormorant breeding sites;
- greater availability of suitable prey fish at many sites, especially in recreational fisheries and aquaculture sites as a consequence of stocking, nutrient enrichment (eutrophication) processes and/or changes in fish species/size composition;
- a wider range of suitable habitats for cormorants to breed, roost and feed, including flooded, man-made gravel pits and quarries; new water supply reservoirs; regulated rivers; nature reserves; newly-constructed stillwater fisheries.

It is readily evident from this that cormorants will not disappear 'naturally' at current levels of food supply and that conflicts with fisheries will not resolve themselves.

This **Toolbox** is intended to help guide those who seek to reduce cormorant predation problems by, for the first time, presenting an authoritative, accurate and useable guide to the management techniques available and the most suitable techniques to employ at different sites. Although the **Toolbox** focuses on management of cormorant conflicts related to the Great Cormorant, many of the techniques are equally applicable to other cormorant species, including the Pygmy Cormorant (*Phalacrocorax pygmeus*).

'Under no circumstances should it be assumed that because a particular technique is described in this Toolbox, it can be used legally in a specific country or region. You MUST check the legal position before proceeding to apply any technique at a particular place or time. Your national or regional authorities should be consulted; additional guidance is also available from the European Commission'

3 EUROPEAN CORMORANT MANAGEMENT TOOLBOX

3.1 Background And Some Words Of Caution

Across Europe there are considerable variations in cormorant population sizes, breeding and wintering aggregations, and migration patterns. Hence, problems occur at different times of the year and concern both wintering and breeding birds. Scientifically, the population dynamics of the birds are complex. Moreover, there is a diverse range of fishery interests affected by cormorant depredation across Europe in freshwater, brackish and marine habitats, affecting commercial fisheries, fish farms (intensive and extensive), recreational angling, and natural or semi-natural habitats. On occasions, cormorants may also pose a potential threat to the status of rare or endangered fish species.

The efficacy of control measures will therefore depend on many factors, including whether birds are sedentary or migrating (i.e. the levels of site fidelity — whether local populations are 'open' or 'closed'); the proximity of alternative foraging sites; the numbers of birds and food resources in the area; the features of specific sites, particularly the size or area of water; and inter-annual variations in cormorant numbers in particular areas — for example, due to weather patterns and climate.

These are all important issues when considering suitable deterrent measures, and they are likely to play a key part in determining the efficacy of any particular technique at a particular site. It is also clear that there is no single solution — deterrents may work at some sites or in some situations but not at others, and this makes it very difficult to generalise. These potential constraints need to be recognised and taken into account when applying cormorant management tools.

It should also be remembered that predation on fish by cormorants and other fish-eating birds, and predation by fish on other animals, is a normal part of the natural interactions that occur between species in aquatic habitats. It is also true that the numbers of predators are typically closely linked to, and governed by, the availability of suitable prey species. In the absence of good access and ample prey, predator numbers will fall. This 'density-dependent' regulation of cormorant numbers underpins the usefulness of many of the methods described in this **Toolbox**.

To some, the resolution of conflicts lies in the supposed effectiveness of shooting to kill cormorants on an individual site basis or as part of a coordinated cormorant cull. The notion that 'one dead cormorant is one less that will feed on fish' is understandable, but the birds' population dynamics and behaviour mean that actual situations tend to be far more complex. Cormorants are attracted to, and will always attempt to exploit, the best feeding sites, and these will often coincide with those that are most valued by recreational anglers, commercial fishermen or fish farmers. Because of the mobility of cormorants, killing birds at such prime sites commonly creates opportunities for new birds to replace those that have been killed, a process that can occur within days at some sites and months at others, depending on the time of culling and other factors. Even where large, organised cormorant culls take place each year, bird numbers often recover quickly as replacements move in, particularly at sites that are on established cormorant migration routes. Such cases highlight the fact that killing birds may not provide the ready solution to cormorant conflicts that is often imagined.

It must be emphasised that cormorant-fishery conflicts are not simple. Studies have also confirmed that the mere presence of cormorants at a site may not indicate that there is a serious problem. While the birds can seriously

deplete stocks at some sites, their impact elsewhere can be relatively minor. The purpose of this document is to provide some practical advice on the options available for those who may want to deter cormorants from visiting a site, or reduce the birds' impact on resident fish stocks. The Toolbox covers: (a) a range of cormorant deterrent techniques (auditory, visual and chemical), (b) options for excluding birds, the modification of the habitat or management of fish stocks in order to minimise interaction with the birds, and (c) the use of lethal control measures.

3.2 What Is The Toolbox?

This Management Toolbox reviews and assesses those techniques that have been employed for managing cormorant-fishery conflicts. Any particular technique (or 'tool') may be applicable at different stages of the annual-cycle of the birds (e.g. breeding or over-wintering) and at a variety of scales — for example, to protect a single pond, a particular, defined habitat or a commercial fishery along a section of coast, or to deter birds from a larger, 'sensitive' area of water.

3.3 What Does The Toolbox Contain?

The Toolbox includes information on techniques that have proved to be successful in managing cormorant conflicts in at least some contexts. It also describes techniques that may have only limited, short-term benefit. The aim has been to provide as comprehensive a list as possible of options that might be applicable at different sites, and all of them have worked at some time in some places. Emphasis is placed on the most effective tools, with detailed descriptions of these techniques. Where appropriate, photographs and Case Studies have also been included by way of illustration.

3.4 Legal Issues

The Toolbox includes both lethal and non-lethal techniques and discusses the main advantages and constraints surrounding their use. However, it is important to remember that cormorants are afforded protection under the Wild Birds Directive 79/409EEC, and in most countries additional cormorant protection legislation applies.

In different countries and/or regions, further legislative controls may also constrain what techniques are permissible for controlling birds. Typically, these regulations cover issues such as:

- Techniques and the personnel permitted to use them
- Location
- Protected and special areas
- Target and non-target species
- Timing
- Breeding periods
- Nests and roosts
- Proximity to fish or fishing gear
- Monitoring of results and reporting

No attempt is made to detail the various regional, national or international regulations in the Toolbox or to consider possible ethical issues such as when and where lethal measures might be applied, but they need to be recognised and taken into account when applying any of the techniques described here. Under no circumstances should it be assumed that because a particular technique is described in this Toolbox, it can be used legally in a specific country or region. You MUST check the legal position before proceeding to apply any technique at a particular place or time. Your national or regional authorities should be consulted and will be able to advise you further. Additional guidance is also available from the European Commission in respect of applying derogations under Article 9 of the Birds Directive. Some further information on legal and ethical issues is provided in **INTERCAFE's** publication 'Essential Social, Economic and legal Perspectives on Cormorant-fisheries Conflicts'.

3.5 Is A Particular Tool Suitable For Me?

For each main technique or group of similar ones, the descriptive text provided is followed by a general evaluation in terms of a tool's:

- Efficacy — including its longevity
- Practicability — how easy (or otherwise) it is to apply the technique
- Cost — some tools are not expensive, while others may incur considerable costs
- Acceptability — for example, there may be aspects of the method that disturb others or compromise nature conservation

This evaluation is based on published information and discussions with stakeholders and other experts involved in the

INTERCAFE COST Action. It also builds on a similar evaluation that was included in the earlier REDCAFE report (available from: http://www.intercafeproject.net/pdf/REDCAFEFINALREPORT.pdf).

'Protecting a fishery from cormorants is very often not easy, and sometimes it may be impossible'

The aim of the Toolbox is to provide as objective an overview as possible of the effectiveness of specific cormorant management techniques. However, it must be remembered that techniques to reduce cormorant predation at fisheries can be site-specific and variable.

3.6 How Do I Use The Toolbox?

Cormorant-fishery conflicts affect different fishery sectors (including aquaculture, commercial fisheries and recreational or 'angling' fisheries) across a broad spectrum of natural and man-made aquatic habitats. However, a range of factors will influence the efficiency of any particular technique at an individual site, and this makes it impossible to provide specific recommendations for different sectors or habitats.

One of the key factors affecting whether a technique is successful or not will clearly be the size of the site that one wants to protect, and this will inevitably constrain the use of certain tools. However, even at very large sites, localised deterrents may have some role to play in protecting sensitive area — for example at netting stations, migration bottlenecks or aggregations of fish at spawning sites. Furthermore, since deterrents may often be most effective when used in combination, it is not the intention of this Toolbox to narrow down potential options for users by guiding them to specific tools. Rather, the aim is to provide users with a number of options that might be applicable for particular sectors or situations.

Thus, this Toolbox is not merely a list of recipes that, if followed, will instantly solve any particular problem that cormorants are causing at a fishery. Indeed, there appear to be no easy solutions to the diverse problems that cormorants are thought to cause. Protecting a fishery from cormorants is very often not easy, and sometimes it may be impossible.

The effective use of mitigation techniques will also require consideration of: (1) the time that can be devoted to deploying them; (2) the size of the problem (including the time of year, numbers of birds, and type and size of fishery); (3) the behaviour of cormorants; (4) the associated costs (outlay versus losses); and — often — (5) local, national or international legislation on the use (or otherwise) of particular techniques.

Many of the techniques available work by persuading cormorants to leave one particular feeding site and move elsewhere. The birds' 'willingness' to move somewhere else will depend on both the severity of the persuasion to leave a site, but also, and perhaps most importantly, on the relative attractiveness of alternative feeding sites in the area. Thus, the effective deployment of mitigation techniques at a specific location may depend on a good knowledge of a much wider area.

Given these undoubted complexities, it is perhaps not surprising that no magic solution exists for reducing cormorant predation at fisheries. The use of deterrents or other mitigation techniques is thus an issue that individual fishery owners or managers will need to address. It is hoped that the range of techniques described in this **Toolbox** (Figure 1) will help such people to experiment with different techniques and allow them to be creative in devising mitigation programmes that can better protect their stocks from cormorant predation.

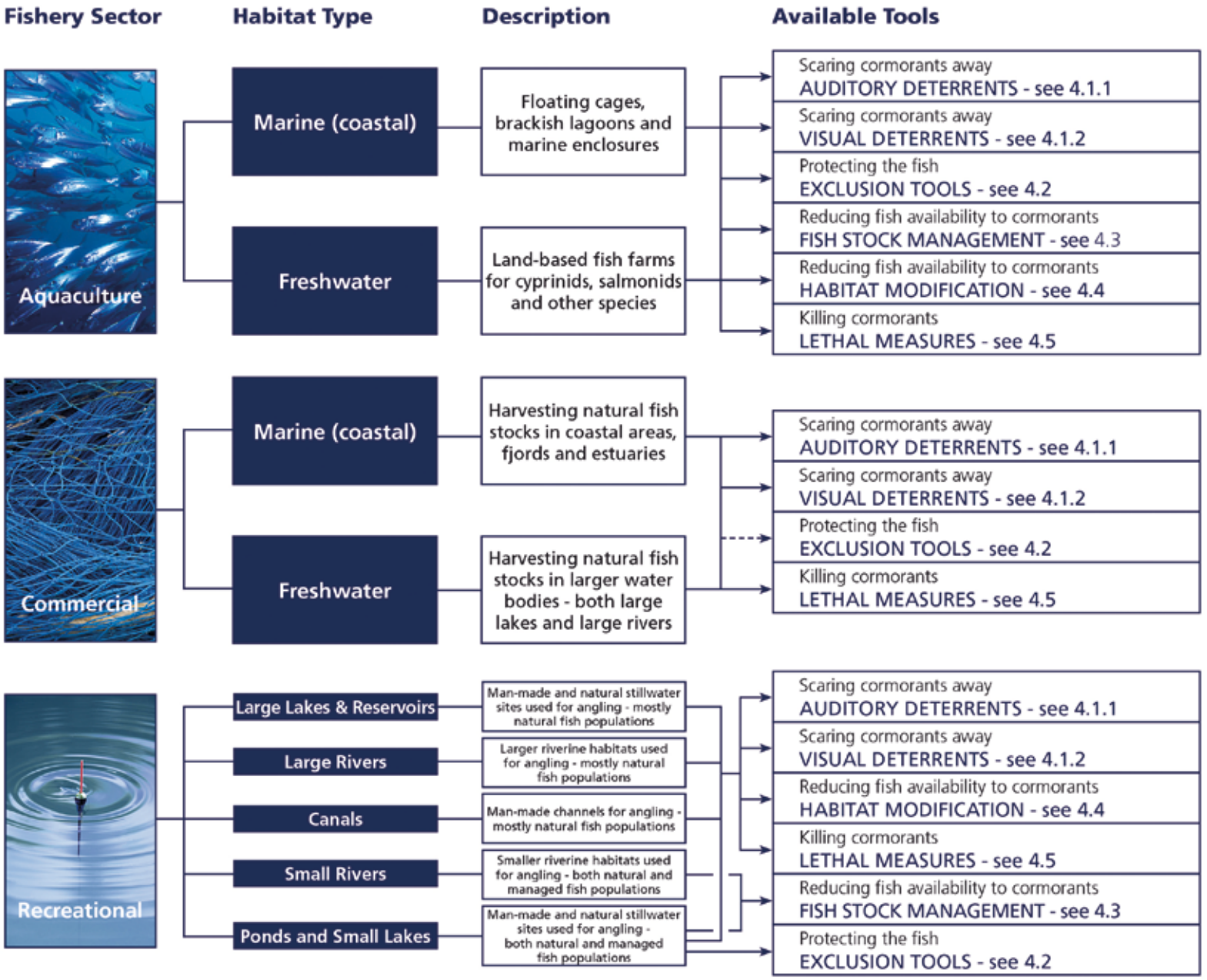


Figure 1 Guide to navigating the Toolbox. This illustrates the main fishery sectors and the habitat types affected by cormorants and guides users to the subsequent sections of the Toolbox, where the techniques most likely to be useful in any particular context are described. The dotted arrow indicates a tool that might be useful under certain conditions although it is largely untested in practice.

4 CORMORANT MANAGEMENT TOOLS

Limiting the interaction between cormorants and fish can be achieved in a number of ways, each falling into one of four broad categories of action:

1. Scaring cormorants away from a fishery.
2. Protecting the fish — by preventing cormorants from reaching them.
3. Altering fish availability to cormorants — by making a fishery less attractive as a foraging site.
4. Reducing overall cormorant numbers — for example, by killing cormorants locally to reinforce scaring at specific sites, killing them more intensively, or reducing their reproductive efficiency.

In addition, under some circumstances cormorant-fishery conflicts can be addressed through the use of financial or other compensation measures.

The **Toolbox** aims to summarise information on each category of action with regard to the methods available, their efficacy, the constraints on their deployment or use, and the relative costs. The aim is to provide a broad overview of the effectiveness of different management options for different cormorant-fishery conflict situations.

4.1 Scaring Cormorants Away From A Fishery

The basic philosophy behind techniques to scare birds away from a fishery is that cormorants are startled sufficiently to move to another foraging site by means of auditory, visual or even chemical deterrents. Clearly, the effectiveness of these techniques relies on: (1) the deterrents being sufficiently frightening to cormorants to make them move elsewhere; and (2) there being a 'better' alternative site for them to move to.

The main drawback of these techniques is that cormorants eventually (often quite quickly) realise that they offer no real threat and the birds become 'habituated' to the noises, sights or smells, ignoring them thereafter. However, there is good evidence that birds are scared consistently by human presence if they perceive that humans are associated with danger. Where this is not the case, the birds can sometimes be approached at close quarters and show no apparent fear of man.

The key to the successful use of auditory and/or visual deterrents seems to be to make them as unpredictable as possible by changing their location and frequency of use, and by using a number of techniques in combination. If these deterrents are used in conjunction with highly-visible human presence, this will increase their overall efficacy but may reduce their cost-effectiveness. As with many other techniques, it seems best to operate these deterrents before or as soon as birds arrive at a site — thus preventing them from getting used to the area as a foraging site in the first place. Once birds have learned that a site is good for foraging or breeding, it will be much harder to deter them from coming to it.

4.1.1 Auditory deterrents

A number of commercially produced noise-generating bird scarers are available — for example, through local agricultural suppliers. These vary considerably in their price and complexity, from simple humming tapes to relatively sophisticated, automatic devices such as gas cannons. A general consideration with all these devices is noise nuisance, and any national and local controls on their use must be taken into account.

4.1.1.1 Gas cannons

Gas cannons are deterrent devices that produce loud banging noises by igniting a mixture of gas (either acetylene or propane) and air under pressure. The frequency of detonation can be regulated by adjusting the gas feed or with an

Gas cannon. Photo courtesy of Thomas Keller.

automatic timing device. Most cannons produce a single bang at pre-set, timed or random intervals, but some devices can produce double or triple bangs, and rotators are available so that the noise can be aimed in different directions. Some are regulated by computer to produce a random length of the volley and with random intervals between volleys, or they may incorporate light detectors to allow the device to be turned off at night.

A gas cannon is relatively expensive and prices vary, depending on whether it is electronic or mechanically ignited; whether it is a single, double or multi-bang device; and whether features such as a rotator or mechanical or electronic timer are fitted. The unexpected noise produced by a cannon is similar to the noise of a shotgun and causes a startle reflex, thus prompting birds in the vicinity to take flight. Their efficacy is reportedly heightened where birds have had prior experience of shooting to kill.

Gas cannons are widely used throughout Europe at aquaculture facilities and to protect inland fisheries, particularly at smaller sites. They have also been deployed at specific locations or for particular times at larger sites — for example, to protect fishing gear (e.g. fixed nets), or to restrict local damage for short, highly sensitive periods. These might include the draining and harvesting of Common Carp *(Cyprinus carpio)* ponds, during aggregations of breeding or migrating fish such as Atlantic Salmon *(Salmo salar)* smolts, or in the vicinity of obstructions or barriers in rivers that may cause fish to congregate and hence increase their vulnerability to predation.

The effectiveness of gas cannons depends on how they are used, the size of the site to be 'protected', and the availability of alternative feeding areas for the birds close by. Local conditions, such as wind direction and strength, can also affect the intensity of noise. Cannons are more cost effective at smaller fishery sites, and the cost of sufficient numbers to cover a large area may be prohibitive. Researchers have suggested that one cannon can protect 1.3–2.0 ha at aquaculture facilities, if

Vehicle-mounted gas cannon. Photo courtesy of Thomas Keller.

'A cannon firing repeatedly without any variation in timing or direction quickly loses its potential to scare birds'

reinforced with other techniques. A survey of catfish *(Ictalurus spp.)* farmers in the USA indicated varying levels of satisfaction with the use of gas cannons to deter Double-crested Cormorants: around 10% of respondents felt they were 'highly effective' and about half found them 'somewhat effective'; others regarded them as 'ineffective'.

A simple field experiment carried out in the Czech Republic recorded the reactions of cormorants to the firing of a gas gun. A number of cormorant responses were recorded: (a) no reaction; (b) taking fright; (c) diving; (d) soaring and circling; and (e) flying out of the pond. These were found to be correlated with the distance of the birds from the gas gun. Typically, birds up to 300 m away displayed an active response (e.g. soaring and circling, flying out of the pond), suggesting that this method would be particularly effective on smaller fish ponds.

The general consensus of opinion is that gas cannons are most effective when moved every few days, have variable firing intervals and are deployed in combination with other scaring techniques. For example, placing a cannon in a hide used by shooters, and frequently moving it between hides, may prolong the scaring effects of both the shooting and the cannon. Gas cannons employed at fish-rearing ponds in Israel have also been mounted on wheeled carriages or on vehicles to make them highly mobile, where their effectiveness is reinforced by human presence and shooting. Products are also available that combine visual and acoustic stimuli to scare birds — the 'Rotating Hunter' consists of two propane cannons and the metal silhouette of a person that swivels with the force of each bang.

The main reason for cannons losing their effectiveness is habituation — birds get used to the noise and are no longer scared away by it, especially if they have no experience of shooting to kill. A cannon firing repeatedly without any variation in timing or direction quickly loses its potential to scare birds. In such circumstances, cormorants have even been reported to use gas cannons as perches. Although cannons can be effective if the firing frequency and direction are varied, these scarers may be socially unacceptable near residential areas due to public concern about noise nuisance, especially if left to fire at night. However, pointing cannons away from houses and constructing simple straw baffles around them allows the devices to be placed at approximately half the distance of cannons without baffles, with no increase in noise nuisance. As sounds tend to be heard at greater distance at night, gas cannons near human settlements should be turned off or programmed to stop at night, unless Night Herons *(Nycticorax nycticorax)* or other nocturnal birds are also a problem.

Gas cannons may also have an undesirable effect on other wildlife (e.g. birds and mammals) and humans (e.g. fishermen or fish farm workers), and they may also need to be located in secure locations to guard against theft. One must also be aware that the cannon noise may be mistaken for gunshots, and it would be prudent to inform the police, wildlife rangers and, in some countries where they may be deployed near national borders, the military about their presence. It may also be wise to advertise the use of such equipment widely to anglers, or others using a site, as the loud report may be disturbing to those with a nervous disposition or certain medical conditions.

Moreover, in other circumstances the use of gas cannons may be imprudent. For example, at fish over-wintering ponds stocked with very large densities of small fish, the noise of cannons can agitate and stress the fish. At sites in Italy, such stress has reportedly caused fish to move, exposing them to more environmentally harsh conditions and leading to mass mortalities.

4.1.1.2 Pyrotechnics

Pyrotechnic devices are widely used as a cormorant deterrent at aquaculture facilities and to protect inland fisheries, particularly at smaller sites. They produce loud bangs or whistles and emit flashes of light and colour, and they can provide a cheaper and more flexible alternative to gas cannons, depending on the level of use and whether their use introduces additional manpower costs.

There are a wide variety of noise-producing cartridges, including shell crackers, screamer shells, whistling and exploding projectiles, bird bangers, flash/detonation cartridges and flares. These can be fired from modified pistols (with a range of approximately 25 m) or shotguns (range of 45–90 m) and can produce noise levels of up to 160dB. As the direction and intensity of firing can be controlled to suit the bird species and location, an advantage of this technique is that deterrence can be targeted and disturbance of non-target species minimised. Be aware that both the cartridges and the gun require a firearms certificate in some countries, and legal restrictions on their use may also apply. In some countries, pyrotechnic operators need to be licensed or carry special insurance.

Pyrotechnic rocket.
Photo courtesy of Paul Butt.

Alternative pyrotechnics include bird-scaring rockets — similar to recreational fireworks — and rope-firecrackers. These devices are relatively inexpensive (for short-term use) and easy to use. The rope-firecrackers ('banger ropes') also require little manpower — these are simply lengths of slow burning fuse with bangers inserted at intervals to produce a series of loud explosions at approximately 20-minute intervals. Placing them inside clean, empty oils drums can enhance the noise of the explosions, but particular care is needed to ensure this is done safely. Weather conditions can affect the burning speed of the rope and there is also a danger of creating a fire hazard. As with all pyrotechnics, great care must be taken with their storage and transport.

In Israel, some fishermen have been licensed to use professional fireworks and have also explored the use of remote-control devices to set off pyrotechnics placed at various locations around fish farms. Trials were completed with some success, but this approach was not adopted for widespread use due to the relatively high costs and some technical problems. A large variety of powerful fireworks are available, thereby helping to prevent bird habituation, and many are much less expensive than simple banger shells. However, legal restrictions on their use apply in most countries.

In a survey of Mississippi catfish farmers, 21 of 281 respondents (around 7%) regularly used pyrotechnics. Of these, 24% considered them to be 'very effective', 57% 'somewhat effective' and 19% 'not effective'. Other researchers have reported variable effectiveness in the use of pyrotechnics against different species of fish-eating birds. This may be partially dependent on the availability of alternative feeding and loafing areas for birds.

As with gas cannons, pyrotechnics are not considered effective on large bodies of water and habituation can occur rapidly if they are used too frequently. Moreover, if they are used in large numbers they are also unlikely to be cost-effective. Habituation can be delayed by using pyrotechnics selectively — i.e. infrequently and at close range, and by varying the type of shell used (whistles, bangs, flashes). However, they can be very effective at smaller sites, particularly in combination with mobile, visual scarers, other deterrents, or by occasionally killing individual cormorants.

Pyrotechnics are often used in Israel, in combination with other techniques, in effective deterrence programmes and for effective dispersal of night roosts. It should be noted that their effectiveness may be partly due to the presence of an active human operative and, with the exception of rope-firecrackers, pyrotechnics therefore represent a fairly labour-intensive method of bird scaring.

Pyrotechnics have been used to scare cormorants at several roosts in the Northern Po Delta in Italy, with varying results. They proved useful at smaller roosts, particularly during the initial establishment period. At a large roost (2,500–3,000 birds) established 10 years previously, a large number of pyrotechnics were deployed on several after-dark occasions, with reinforcement using a laser rifle. However, there appeared to be no clear or lasting effects in this instance; the financial costs were high and the logistics complicated, and staff motivation proved difficult during inclement weather conditions.

Nevertheless, pyrotechnics can be an extremely effective and relatively low-cost, non-lethal method of bird scaring. They are easy to operate, the risks of habituation are reportedly negligible if their use is 'randomised' as much as possible (i.e. applied on an *ad hoc*, as-needs basis at different locations) and they pose fewer safety problems than shooting. However, their use should be limited to sites away from residential areas to avoid causing a noise nuisance and problems of public safety. They should also not be used in situations where there could be a fire hazard, such as near dry vegetation. Like gas cannons, the noises can also have negative impacts on other wildlife and humans.

4.1.1.3 Shooting to scare

Shooting to scare is one of the most widely used techniques for deterring cormorants at sites across Europe and elsewhere. It is one of the few techniques that is employed at all types of water body, from small to large and from inland to coastal, as well as at aquaculture facilities. There are fewer legal restrictions on the use of this technique than on shooting to kill (although non-toxic ammunition must be used near water bodies in many places), and in some countries a shooting licence and appropriate insurance may be a legal pre-requisite even for shooting blank cartridges.

Shooting to scare can be used to deter birds or reinforce the scaring effect of other deterrents, such as human presence, gas guns and pyrotechnics. It is more widely

Verey Pistol. Photo courtesy of Paul Butt.

Blanks. Photo courtesy of Paul Butt.

'Shooting to scare is one of the most widely used techniques for deterring cormorants at sites across Europe and elsewhere'

used than the use of pyrotechnics because live ammunition is often cheaper and more readily available. The most commonly deployed weapon is a 12-bore shotgun, although relevant certificates for such use may be required. The safest way to use a shotgun for this purpose is to fire blanks, which are available from local gun dealers. This also avoids any possibility of actions being misconstrued, of birds being injured, and of adding lead to the ecosystem.

Live ammunition can also be used, but care needs to be taken not to kill or wound birds, unless the appropriate authorities approve this. The practice of 'peppering' cormorants with small lead shot pellets in order to deter them is commonly considered inhumane and illegal in most places. A starting pistol can be used as an effective alternative to the use of a shotgun, although care should be taken so that others do not misinterpret this course of action.

It is also possible to purchase a variety of special bird-scaring cartridges. However, these are specially designed to be fired through a signal (Verey) pistol sleeved to 12 gauge and not through a normal shotgun. Appropriate firearms certificates may also be required for these. Furthermore, because of the noise they make and the restrictions on possession and operation, the use of bird-scaring cartridges is probably somewhat limited.

Shooting to scare can be an effective deterrent, and it is sometimes the only option available on a river or still water to which the public have access. It has been demonstrated in a recent study in the UK that shooting to scare can reduce the number of birds present at fisheries for the duration of the shooting period and for a 'post-treatment' period. A large-scale experiment was undertaken involving thirteen, six-week field trials carried out over two years at a range of fishery types (including river and stillwater fisheries, stocked and unstocked sites, and fisheries with and without cormorant night roosts). The experimental design involved three treatments: control (no shooting), lethal shooting and non-lethal shooting (at the same intensity). Each six week trial was divided into three two-week phases: pre-treatment, treatment (when shooting with blanks was carried out) and post-treatment. Numbers of cormorants were then compared before and after commencement of shooting and between control and shooting sites.

The results indicated that shooting (to kill or to scare) significantly reduced the number of cormorants for both the treatment and post-treatment phase. An average bird reduction of over 50% was reported. However, bird numbers recovered to pre-treatment levels over a period of two to six weeks. To be effective in the longer term, this means that such scaring would need to be repeated at regular intervals for as long as cormorants remained in the area. When done properly (e.g. as birds first arrive), and in conjunction with other deterrents, this can be highly effective over a long period of time.

4.1.1.4 Bio-acoustics, acoustics, ultrasonics and high intensity sound

Bio-acoustic deterrents are sonic devices that transmit sounds with a biological meaning — for example, recorded bird alarm and distress calls. Typically, alarm calls are used when birds perceive danger, while distress calls are used when birds are captured, restrained or injured. Both types of calls are usually species-specific and can cause members of the same species to take flight, but they may also elicit a response in other species that are taxonomically related or which closely associate with the call-producing species.

Recorded alarm calls are widely used as bird deterrents, and such biologically meaningful sounds should be more repellent and resistant to habituation than other sounds, although responses vary

between species (e.g. some species of gull [*Larus* spp.] are initially attracted to the noise, apparently to investigate). There are reports of the successful use of broadcast distress calls to deter some species of heron (*Ardea* spp.) and Night Heron. However, in trials in Italy and Israel the broadcast of Night Heron distress calls at night and early in the morning caused unacceptable disturbance to people living nearby.

Researchers have reported that locating sources of cormorant distress calls is problematic. It was discovered that some commercially-sourced distress calls trialled in Italy were actually the cries made by nestling cormorants when calling their parents. Further, it has been noted that the birds rarely seem to make distress calls anyway. Despite repeated attempts by one researcher to induce and record such sounds from injured and captured adult cormorants, and while ringing nestlings, the birds always remained silent. Nonetheless, trials have been carried out in some countries with cormorant distress calls, but the results have suggested that the technique is of short-term use only and ineffective in the longer term due to habituation. Similar reports from North America indicate that distress calls were generally found to be ineffective against Double-crested Cormorants, at least over long periods of time.

The possibility of broadcasting cormorant distress calls underwater to enhance their effect (sound propagates more effectively underwater) has been considered, but it does not appear to have been tested as yet or made commercially available.

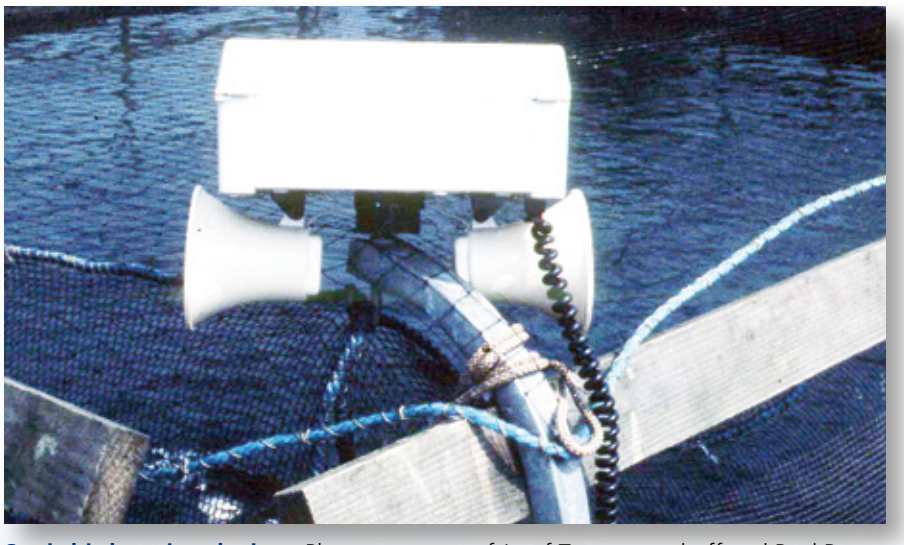
An underwater acoustic system ('Cormoshop'®) has recently been developed and produced commercially in France, based on the calls of the Killer Whale (*Orcinus orca*). Underwater loudspeakers, supported by floats situated 40 cm under the water surface, diffuse sound waves into the water to frighten cormorants when they are diving. Various frequencies have been tested and those at 90 kHz — the frequency of sounds from a Killer Whale — were found to be most effective. The manufacturers have continued to revise the frequency settings and power output to further improve the effectiveness of the device.

Initially, the 'Cormoshop'® system was tested at commercial fish ponds in France and feedback from the pond owners was largely positive. Experience indicated that diving cormorants took flight immediately and stayed away from the protected ponds. However, the device appeared to work only on ponds where the fish density was relatively low (<300 kg/ha). At higher fish densities the system appeared to be less effective, possibly as a result of the cormorant's dive time to catch a fish being shorter because of greater food availability. The system reportedly has no adverse effect on fish behaviour and can be reliably used under all climatic conditions. However, it requires a reliable electric power source and thus may not be applicable at more remote sites.

Units have mainly been used in France and Belgium, although they have also been deployed at sites in Italy and Germany. Initial feedback from Belgium suggests

that birds habituate to the device at extensive aquaculture facilities, and it has reportedly proved too expensive for use at such locations. The device has been used with more success at fish ponds used for recreational angling, possibly as a result of the presence of the device being reinforced by regular human disturbance.

Sonic bird scaring systems that produce a variety of electronically-produced sounds, sometimes associated with randomly-activated lights, are also available commercially. The range of loud and sudden noises they produce can frighten birds but, as they have no biological meaning, the risk of habituation is greater. With



Sonic bird scaring devices. Photos courtesy of Josef Trauttmansdorff and Paul Butt.

static systems, frequent changes in location and adjustment of the sounds produced can reduce this risk, and mobile (e.g. vehicle-mounted) systems that can be used in response to bird problems are more effective, though they are also more expensive due to the labour involved. Some reports suggest such devices can deter cormorants, although a proportion of the birds present were reported to dive rather than fly away.

In the Po Delta in Italy and in Sardinia, extensive trials have been conducted with sonic bird-scaring devices to scare cormorants away from their night roosts and to keep birds away from particular areas within extensive aquaculture lagoon systems where high densities of fish are held over winter. Two commercially-available devices were tested. The trials indicated that electronic sounds could be useful, at least in the short term, to deter groups of birds, but appeared to be ineffective against single birds, particularly if these birds were well used to the area. Habituation was seen as a problem and strong winds dispersing the sound away from the desired direction was also considered to have affected the efficacy of the devices.

Evidence indicates that most species of birds do not hear in the ultrasonic range (>20 kHz) so there is no biological basis for using ultrasonic devices and no evidence that such devices deter birds. Ultrasound loses intensity far more quickly with distance than regular sound, so it is usually ineffective outdoors.

High intensity sounds, such as air horns and air-raid sirens, can distress birds and cause them to leave a site. However, they have a relatively short range and birds appear to habituate quickly to their use. Trials at aquaculture facilities in Israel and Italy with vehicle horns and sirens have reportedly

proved largely ineffective or effective only for short periods. These devices can also cause hearing damage to humans and are generally not recommended for general use. However, sirens mounted on vehicles can provide an effective combination of human presence with an audible deterrent, and they have been used with some success in Israel to scare birds at fish farms.

Sound transmission from all sonic devices is influenced by ambient temperature, wind direction and reflections from surrounding features such as buildings, and this should be taken into account when setting up such devices. As with most methods of bird control, using such devices as part of an integrated approach with a variety of techniques is likely to be more effective and will help reduce the risk of habituation.

4.1.1.5 Other sound-producing techniques

Other sound-producing techniques can also be used to deter cormorants. For example, tapes that produce a humming or clacking sound when they move in the wind can also be used, and the combination of sound and a visual deterrent can be effective (see Section 4.1.2 on visual deterrents).

4.1.1.6 Overview of auditory deterrents

Efficacy

Auditory deterrents can be effective against cormorants. The effectiveness varies with the device chosen, the method of use, the size of the site and the availability of alternative foraging sites to which the birds can relocate. Such devices have a limited range, and this can be influenced by wind strength and direction, ambient temperature, and surrounding features such as buildings. Thus, they are most effective at smaller sites, or at particular locations at larger sites (e.g. netting stations or known predation 'hot spots') to address specific, local problems. All audible deterrent techniques are subject to habituation (birds learn that they pose no danger and ignore them), and hence they are more likely to be of short-term benefit, generally for weeks or shorter periods. However, efficacy can be extended considerably by moving devices regularly or mounting them on a vehicle for maximum mobility, where they are reinforced by human presence, using variable firing intervals and by employing them as part of an integrated control strategy alongside other measures.

In general, techniques such as pyrotechnics and shooting to scare appear to be more effective and longer lasting against cormorants than static devices, probably due to the reinforcing effect of human presence and, where this is used, shooting to kill, as well as the more flexible and targeted means in which they are deployed. Such measures also appear to be more effective if birds are exposed to true danger (e.g. due to shooting or if hunting is permitted) in the surrounding area.

Practicality

Auditory deterrent devices are used widely for a range of bird scaring purposes. They are readily available, relatively easy to deploy and simple to operate. Such deterrents thus rate highly from the viewpoint of practicality for many sites. Legal constraints on the use of some of these techniques may apply and licences or permits may well be required for their operation. Local guidance and necessary approvals should thus be sought prior to using these devices. The deployment of audible deterrents should also take account of appropriate safety issues (e.g. use near members of the public or in the vicinity of sensitive sites).

In addition, there will be a need to guard against the use of pyrotechnics in situations where there could be a fire hazard, such as near dry vegetation. It might also be necessary to consider the security of the device to minimise the risk of possible theft or vandalism (e.g. by deploying the device on an island).

Many audible deterrents require some form of power source, and this may render them more difficult and expensive to deploy, and perhaps impractical, unless there is a supply of electricity or suitable batteries that can be re-charged. It is also important that such devices will operate reliably and effectively in what may be extremely variable environmental conditions.

Costs

The price of auditory deterrents varies considerably and depends on the complexity of the device itself (e.g. from simple humming tapes to relatively sophisticated automatic devices) and the operating costs. Static devices such as automatic gas cannons, bio-acoustic deterrents and sonic devices are relatively expensive, and the costs involved in trying to apply

these over a large area are likely to be prohibitive. However, once purchased, such devices can be used over many years and running costs are relatively low.

The costs of pyrotechnics or shooting to scare are relatively low in terms of the materials, in the short term at least. However, manpower costs have to be taken into account, particularly if dedicated staff are used for bird scaring duties, and recurrent costs can be high if such deterrents are used repeatedly. Staff costs can be reduced where volunteers or local stakeholder groups are involved in bird scaring programmes.

Acceptability

The use of auditory deterrents for deterring birds is widely recognised and accepted. However, general considerations with the use of all auditory deterrents relate to their potential noise nuisance and their indiscriminate impact on non-target species. Auditory scarers may be socially unacceptable in residential areas, and they may also have an undesirable effect on other wildlife and humans in the area (e.g. fishermen or fish farm workers). To an extent, the level of possible disturbance can be regulated by the way these devices are used — for example, by pointing them away from houses or constructing simple straw baffles around them. It may also be wise to advertise the use of such equipment widely to anglers, or others using a site, as the loud bang may be disturbing to those with a nervous disposition or certain medical conditions.

4.1.2 Visual deterrents

There are a number of relatively simple and inexpensive visual deterrents, mainly used for scaring birds from farmland, which can be successfully adapted to deter fish-eating birds at fisheries and aquaculture facilities.

4.1.2.1 Human Disturbance

Human activity has been shown to be consistently effective for scaring cormorants away from fisheries and aquaculture facilities, and it is not constrained on grounds of acceptability to other people as some other techniques often are. Human disturbance is one of the most widely used techniques for deterring cormorants, particularly at aquaculture facilities and at fisheries on smaller rivers and stillwaters, and it can be conducted on foot, using vehicles or by boat. Birds can be disturbed from specific areas either deliberately, by direct harassment, or indirectly through, for example, leisure activities or routine day-to-day activities. However, frequent or extended periods of human presence may be needed for this to be effective. Thus, options to encourage or extend incidental human presence at 'problem' sites might be considered.

Human presence is also a feature of many bird deterrent methods, and it should be appreciated that it is difficult to separate the effects of another deterrent (e.g. pyrotechnics) from the effects of human presence. Cormorants can habituate to human presence, particularly if this carries no perceived threat, so the simultaneous use of other deterrents is advisable.

The timing of human activity is important. Cormorants normally leave their roost before sunrise and feed most actively just after dawn, so human presence needs

'Timing of human activity is important'

Whilst some types of human disturbance will be innapropriate at fisheries, this is a consistently effective method of deterring Cormorants.
Photo courtesy of Paul Butt.

to be targeted at this time. This will be easier where personnel live on, or very close to, the site to be protected, but it may still prove to be costly or impractical. Nevertheless, human presence over a reasonable period has the advantage that it will enable an accurate count to be made of the numbers of birds affecting a site and, thus, better assessment of the extent of any problem. However, it might be noted that a study in Israel showed that cormorants shifted their main feeding time from early morning — when worker presence was high — to early afternoon, when the workers went to lunch.

Although the use of a dedicated human scarer is likely to be more expensive than other visual and acoustic methods, these costs can be offset by a greater reduction in losses. Costs can be particularly high if specific working time is dedicated to this activity and other costs are taken into consideration (e.g. fuel costs for vehicles), but they can be relatively low where human presence involves volunteers (e.g. unpaid anglers or hunters). Casual scaring associated with routine day-to-day activities can also be effective and of low cost. However, as with all scaring techniques, the success of human scaring is dependent on alternative feeding areas being available.

4.1.2.2 Scarecrows

Scarecrows are a traditional, widely used method for scaring avian pests. These are sometimes designed to mimic the appearance of a predator (e.g. a bird of prey), but they are most commonly human-shaped effigies, usually constructed from inexpensive materials. In general, however, motionless devices either provide only short-term protection or are ineffective, as the threat from them is perceived, rather than real. Some birds reportedly even begin to associate the presence of scarecrows with favourable foraging conditions. In a survey of fish hatchery managers in the United States, only one of the 14 hatchery managers (7%) who commented on the effectiveness of various control techniques said that scarecrows had a high success rate against fish-eating birds; six (43%) said they had no effect.

In a survey of 13 freshwater fish farms in the Modena district of Italy, where damage from 11 fish-eating bird species was reported, the owners or managers of four farms reported that human-shaped and/or moving scarecrows had no effect, three reported success for a matter of days and only two indicated benefits lasting weeks or months.

To maximise the effectiveness of scarecrows, it is recommended that they are made to appear life-like, possess biological significance, be highly visible and have their location changed frequently to delay habituation. Fitting scarecrows with loose clothing or bright streamers that move and create noise in the wind can also enhance their effectiveness. Alternatively, scarecrows might mimic clothes worn by active human scarers. For example, dressing both scarecrows and the farmers in bright yellow raincoats with hoods and having the scarecrows 'hold' a black pipe (as a replica gun) enhanced the efficacy of scarecrows at an Israeli aquaculture facility. This scaring was reinforced by periodic shooting in the area, undertaken by people dressed in similar yellow, hooded coats.

Scarecrow with replica gun and dressed in yellow coat.
Photo courtesy of Simon Nemtzov.

Revolving scarecrows are brightly coloured devices that spin slowly as the wind blows. Some are human-shaped, while others consist of a revolving square, sometimes painted with large predator eyes (also known as 'hawkeye' deterrents). Both designs can be enhanced by the addition of a mirror that flashes as the device revolves. As these devices are wind operated, there is minimal maintenance and these devices are relatively inexpensive.

There are many types of automated scarecrows available for fishery use, most of which have been adapted from scarers used in agriculture. The more sophisticated devices are powered by 12-volt car batteries, and they display and collapse on a controlled-time basis or with motion detectors. These scarecrows can also be fitted with various extras such as hooters, sirens and lights.

Revolving bird scarer — 'predator eyes'. Photo courtesy of Paul Butt.

The most effective techniques appear to be those that simulate shooting through the use of effigies that suddenly appear from cover. One example is a model of a man with a gun that is attached to a gas cannon in such a way that the effigy appears a few seconds before the cannon is fired. This can also be used for purely visual scaring when simultaneous use of the cannon is inappropriate.

Large (around 5 m high), brightly-coloured inflatable 'men' have also recently been produced, primarily for advertising purposes. This type of device is powered by an air pump in the base, and it flaps and sways, both in a breeze and due to the continual flow of air through the device. The long arms also wave and flap about. The devices are thus highly visible over relatively long distances, and in the UK they have reportedly been successfully used against cormorants. A potential disadvantage, however, is that the inflatable 'men' require sources of electrical power with which to operate the air pumps.

Inflatable 'Scarey Man' deterrent (top), and inflatable 'man' (right). Photos courtesy of Paul Butt and http://www.immagoinflatables.co.uk/skyguys.html.

One drawback is that automated scarecrows can be quite expensive to purchase and maintain, and unless the site is secure (e.g. an inaccessible island) they can be stolen or vandalised. Trials with these devices have had some success in reducing the presence of cormorants (and herons), but it is commonly reported that birds habituate to the devices quite quickly, and animated scarecrows have been reported as 'ineffectual' against cormorants at some sites. Regularly changing the position of such devices is

recommended to maximise what effectiveness they may have.

Both static and animated scarecrows are commonly used at aquaculture facilities and fishery sites, particularly smaller ones. The major drawback with scarecrows, however lifelike they may be, is that they do not present a threat that is sufficiently alarming to birds under most circumstances. Consequently, over a period of time, birds learn that effigies do not represent an actual threat and begin to ignore them. To increase the threat and therefore lengthen the time before habituation, it is recommended that all these devices are moved regularly, rather than left in one place. Moreover, devices should not be left in place once cormorants migrate from an area because, when the birds return, the period of habituation can be particularly short.

The effectiveness of scarecrows can be reinforced with other sound-producing or visual deterrents, or, to improve effectiveness, by periodic human activity, especially if they are dressed like the scarecrows.

4.1.2.3 Predator models

Model raptors deter birds by mimicking real birds of prey and creating fear and avoidance behaviour in the target species. Many potential prey species react to predator models. However, the strength of the response varies between species, and model raptors fail to incorporate behavioural cues, which may be critical to the induction of fear and avoidance in the target species. Model birds of prey are reported to be effective at scaring cormorants at some sites. However, there is evidence that the avoidance response to large avian predators is, in part, a learned behaviour. This may diminish the potential for the wider application of this technique against cormorants, since its main avian predator across Europe, the White-tailed Eagle *(Haliaeetus albicilla)*, is absent from many areas where cormorants are present.

'Model birds of prey are reported to be effective at scaring cormorants at some sites'

The flying of live, trained birds of prey across bodies of water by a falconer might also be used. This has been tried in Israel. However, although its efficacy was relatively high, the farmers stopped using the birds due to the very high cost.

While most raptor models are inexpensive and easy to deploy, cormorants can rapidly learn that the model poses no threat, become used to its presence and no longer react. The deployment of a Peregrine Falcon model adjacent to cormorant feeding areas in the southern Po Delta, Italy, appeared to be largely ineffective and tends to support this view. Thus, the effectiveness of such models is increased if they can be made to look lifelike, are animated and moved frequently.

Another form of predator model that has been used is that of tethered floats made to resemble the head of a crocodile or alligator. These floats are distributed around the pond and purportedly can deter water-birds from landing on the pond. It is not known whether these have been used successfully against cormorants.

Mobile scarecrow dressed identically to local workers and also incorporating an auditory deterrent device. Photo courtesy of Paul Butt.

4.1.2.4 Displaying corpses

The deployment of replicas or actual dead individuals in a manner which signals danger to members of the same species can be used as a visual deterrent for many bird species, especially crows ('corvids'). Reportedly, corpses have to be in good condition to remain effective and, as with other static deterrents, they should be moved frequently to reduce habituation. Efficacy depends on the availability of alternative foraging sites and is enhanced when it is reinforced with additional deterrent techniques. While this technique is reportedly highly effective for corvids and there is some evidence it has been effective against egrets (*Egretta* spp.), it is not clear whether or not it deters cormorants.

The desirability of displaying corpses in areas accessed by the general public may also need to be taken into consideration in case the corpses raise public concern and complaints. There are also other considerations if real corpses are used, notably because of possible pollution arising from decomposition, particularly in fish farm areas, and health and safety fears about the possible spread of avian 'flu.

4.1.2.5 Balloons

Helium-filled balloons are used as an inexpensive method of bird deterrence in agriculture. Their effectiveness can be enhanced by the inclusion of eyespots, consisting of a circular pattern that resembles the general appearance of vertebrate eyes. Two circular eyespots arranged horizontally, each containing concentric rings of bright colour, appear to be the most alarming and effective designs. Those that have a three-dimensional appearance may further enhance the effect, and large eyespots are considered better than small ones. Although easy to set up and move around, balloons can be easily damaged in high winds and can deteriorate in sunlight, leading to a loss of helium and thus height. Balloons also need to be checked regularly to ensure they cannot break free from their moorings and present a hazard to aircraft. Their use near aerodromes may be restricted by air navigation regulations. A cheaper alternative is to fill the balloons with pressurised air and to hang them from T-shaped poles.

Raptor kite. Photo courtesy of Paul Butt.

Balloons, and other visual scaring devices, have been used against cormorants to increase the deterrent effect of other physical exclusion devices such as wires and floating ropes (see 4.2).

Studies indicate that the effectiveness of balloons at scaring birds varies between species, the eyespot design and with the mode of presentation. However, effects are commonly only short-term and birds quickly habituate to them. In some places where hunting takes place, such balloons have been used as opportune targets and their use to help deter cormorants has had to be abandoned.

4.1.2.6 Kites

Kites and kite-hawks are commercially available, airborne devices that are meant to act as mobile model predators which 'target' birds perceive as a threat. Kites commonly bear an image of a soaring raptor and are tethered to the ground. Some varieties are secured to a length of line (commonly about 80 m), but these only operate in a wind and, once grounded, have to be re-launched manually. Alternative models are tethered to a flexible 13 m pole and re-launch automatically when the wind starts blowing. The 'Helikite™' is a cross between a large helium balloon and a kite, which 'flies' above a pole. This has the advantage that it does not need wind to stay in the air.

Like balloons, kites and kite-hawks can be damaged by strong winds and may be difficult to keep up in the air when wind speeds exceed 8 km/hr. Since they pose no real

threat to birds, do not behave like raptors, and remain visible for long periods, birds quickly habituate to these devices. Hence, they are effective only over a small area and for a short period of time. As with balloons, their use near aerodromes may be controlled by air navigation regulations.

4.1.2.7 Radio-controlled model aircraft

Radio-controlled aircraft have been used to scare bird pests since the early 1980s. Although mainly used over airfields, this technique has also been applied at other sites, including deterring cormorants and herons at fisheries and aquaculture facilities. For cormorants, experience has shown that model aircraft should be used to scare birds while they are still in the air, as birds already on the water are only encouraged to dive. At larger, land-based fish farms it has been estimated that one model aircraft is required for approximately every 100 ha. Using a falcon-shape aircraft, or a conventionally shaped aircraft painted with a raptor design, can enhance the efficacy of this technique. While quite effective, the use of model aircraft is relatively expensive, labour-intensive, not suitable in bad weather and requires skilled operators — training to become fully competent can take up to two months

In Finland, an attempt to scare cormorants was made using a small, wind-driven helicopter rotor mounted on a tripod. Although the efficacy of the device was not fully monitored, it is thought to have been partially successful.

4.1.2.8 Lights

Flashing, rotating, strobe and searchlights are a novel stimulus to birds and can produce an avoidance response. Lights may be relatively ineffective during daylight hours but they may be particularly useful for deterring night-feeding birds such as herons, or at night roosts. They are easy to deploy and require very little maintenance, but birds will quickly become habituated and so lights are best used in combination with other deterrent methods. They should not be deployed where they might cause a visual nuisance to neighbouring properties or near airfields.

'Lights may be relatively ineffective during daylight hours but they may be particularly useful at night roosts'

4.1.2.9 Mirrors/reflectors

Mirrors and reflectors work on the principle that sudden bright flashes of light produce a startle response and so drive birds from an area. For example, CD discs are highly reflective and can be hung on wires or other objects where they will move with the wind to deter birds. Rotating, reflective pyramids have also been developed that are powered by a 12-volt battery and deflect light into the air at the angle of the birds' approach. These automatically switch off in the dark and will run for several weeks between battery changes. Although inexpensive and easy to put up and relocate, the effectiveness of mirrors and reflectors as a bird scaring technique is variable.

In a survey of 336 fish hatchery managers in eastern USA, eight reported using tin reflectors of which seven said they had limited or no success as a depredation control technique. However, it is known that reflectors can be effective at deterring cormorants at some sites, particularly in sunny locations. For example, in Israel, hand-held mirrors are reported to be very effective. As with many other deterrent techniques, they are best combined with other methods of scaring. For instance, on a large lake in Greece, mirrors and audible deterrents have been used successfully to deter cormorants from sites close to the shore (see Case Study No. 1).

4.1.2.10 Reflective tape

Tapes can best be regarded as a combined visual and exclusion deterrent (see Section 4.2.2). A wide variety of twines and tapes are readily available, including varieties such as Mylar® Tape, which has a metal coating on one side that reflects sunlight and also produces a humming or crackling noise when moved by the wind. Tapes are relatively cheap and easy to deploy, but they can break easily in bad weather conditions, necessitating extra labour for repairs and, potentially, causing an unsightly litter nuisance. Good maintenance of the tapes is essential in order to stop gaps resulting from broken tapes being exploited as entry points by birds. Strips of reflective tape are often hung from wires that are stretched across fish ponds (see Section 4.2.2) to make the wires

more visible and to increase their effectiveness as deterrents.

Reflective tapes are in regular use at aquaculture facilities in a number of countries (e.g. Germany, Italy and UK), and close configuration of these tapes can provide successful protection, particularly if an alternative feeding area is available nearby. However, since the tapes are short-lived, the technique is probably best suited to protecting small areas of high value stock in the short term.

A cheap source of reflective tape is the magnetic tape in old video cassettes, since this is highly reflective and easily available. However, it is inadvisable to use tape from video cassettes with a play length of longer than two hours, as these are made of thinner (and more breakable) tape.

4.1.2.11 Flags, rags and streamers

Flags, rags and streamers, including reflective silver or Mylar® streamers, can be readily deployed at fishery and aquaculture sites and — potentially — also at roost sites. These are cheap and easy to deploy and can prove effective deterrents, in the short term at least. Their success depends on alternative feeding, roosting or loafing sites being available nearby.

4.1.2.12 Lasers

As the demand for non-lethal, environmentally safe methods of bird scaring has increased, there has been increasing interest in the use of lasers to scare birds. Lasers, particularly ones that work under low light conditions, are an attractive alternative to other bird scaring devices since they are silent and can be accurately directed over distance on specific problem birds. Birds are startled by the strong contrast between the ambient light and the laser beam, by the bright spot moving toward them on the ground or in the tree and by the actual beam when it reflects dust particles and appears as a large 'stick' moving toward them. The laser light need not be shone into the bird's eyes to startle them, and indeed it is inadvisable to do so. During low light conditions this technique can be applied very selectively, but at night the light beam is visible over a large distance and hence can cause non-selective disturbance. These devices are ineffective in daylight and in misty or foggy conditions.

'Birds are startled by the strong contrast between the ambient light and the laser beam'

The possession and use of lasers may be prohibited or restricted by legislation or be subject to a licensing regime, depending on the power of the laser being deployed. There are growing safety concerns regarding the availability and use of lasers and calls for tighter regulation in some countries. Thus, the legal aspects of using this technique should be checked with the local authorities before any laser devices are considered for deployment: laser devices should only be used within the limits of appropriate laser safety regulations.

From a safety point of view, shooting a laser light must be regarded the same as shooting a bullet — the operator MUST be sure of the precise target and what the end of the beam will hit. Some lasers can be dangerous at short or even large distances, and proper training and adherence to local laws is essential. Lasers can blind people or animals, permanently or temporarily, and this can also lead to unexpected accidents (e.g. car crashes) if devices are used inappropriately.

Trials with low power (5 mW) red laser (650 nm) guns, such as the Desman rifle®, in France, Italy and the UK have demonstrated that cormorants are sensitive to this laser light and that these devices can be effectively used at cormorant roosting sites. In one trial in the UK, conducted during cloudy weather, most of the cormorants at a night roost were scared away within 20 minutes, and treatment over consecutive evenings caused the temporary desertion of the roost.

In similar trials in roosts in the northern Po Delta, Italy, birds left the roost almost immediately. In Italy, lasers have been successfully used against birds in both tree roosts and bankside areas, sometimes hundreds of metres from the bank- or boat-based operator. The gun 'scope' on laser guns proved useful to accurately target the laser light, and the use of a light amplifier also helped to enhance the efficacy of the device

in the dark. It was reported that lasers were particularly effective at preventing the establishment of new roosts, especially when used in conjunction with shooting to scare techniques.

Similar findings have been demonstrated at other cormorant night roosts, although in some trials the laser gun has been less effective, with some birds failing to leave the roost site (e.g. if the bird is facing away from the light source), thereby discouraging other birds from leaving, too. This reinforces the desirability of deploying a mixture of cormorant scaring devices and techniques.

Laser guns are available commercially for avian deterrence (e.g. Desman rifle®, Avian Dissuader), and some manufacturers also provide training in their use. Other, automatic laser devices have been developed for deterring birds, particularly near airfields to reduce the risk of 'bird strike'. However, these devices are relatively expensive. Due to concerns about the safety of such devices for humans, one commercially available laser gun was tested for safety at the UK Government's Defence Evaluation and Research Agency (DERA). This was found to be safe if it was not pointed at an unprotected human eye within a distance of 155 m, although the safe distance was considerably reduced if viewed with binoculars.

Green lasers (530 nm) are also available and tend to be brighter than red lasers of the same power level. Green lasers are being sold commercially as laser guns for bird scaring, but these are as expensive as the red laser guns (above). However, low-cost, hand-held green laser pointers are also available with a wide variety of power levels, and these have been used successfully for bird scaring at night roosts in Israel and Italy. Low power lasers of less then 5 mW have fewer legal restrictions, though these can potentially still cause eye injuries, and can be effective at ranges of up to a few hundred metres. Green laser pointers of 20–30 mW are effective over larger distances (1–2 km), but usually carry more stringent legal restrictions and safety standards than the 5 mW lasers, reflecting the greater risk that they pose. Green laser pointers of 50, 100 or even 200 mW are also available, but these are increasingly dangerous and apparently no more effective in scaring birds than the less powerful ones. It is anticipated that further controls are likely to be placed on the availability and use of lasers and thus particular care is needed to ensure compliance with local regulations, as well as to ensure safe usage where this is appropriate.

4.1.2.13 High-Pressure Water Jets

High-pressure water jet systems have been successfully tested on Carp ponds in Germany. Aside from deterring predators and making the fish less accessible, a positive side-effect of this technique is that the ponds are also aerated, an important benefit during summer when the dissolved oxygen in Carp ponds can fall to very low levels.

A similar device has also been used in Sweden for protecting circular fish ponds from gulls and terns (Sterna spp.). This rotating device had four arms that sprayed a mist of water over the ponds, reducing visibility and preventing birds from seeing the fish. The spray also provided shade by diffusing direct sunlight, and oxygenated the water. The latter technique was not tested against wading or diving birds, but both methods may be useful to deter cormorants, particularly at smaller ponds on fish rearing sites. The potential for their use in protecting larger, irregular water bodies may be limited because of the cost and the practical installation difficulties.

4.1.2.14 Dyes, colourants and turbidity

There has been little research into the use of dyes or colourants to deter fish-eating birds, but it is known that cormorants are visual feeders, in part at least, and that birds can abandon feeding sites in response to changing water quality conditions such as turbidity (i.e. reduced water clarity). Studies have also indicated that the foraging efficiency of egrets was reduced by increasing the turbidity in trial ponds (obtained by dilution of natural sediment). Thus, some researchers have suggested that such measures might represent a cost-effective method for protecting stocks at fish farms or in ponds and small lakes, since these could be relatively easy to apply in such small, confined water bodies. In practice, such an approach may conflict with fish husbandry practices in fish farms (and perhaps feeding of the fish).

Equally, the practice of deliberately increasing turbidity at a site may be questionable from an acceptability viewpoint on biodiversity/ aesthetic grounds, although the

presence of benthic (i.e. bottom feeding) species such as Carp at fisheries often has this side-effect, particularly at small stillwater sites where stocking rates are high. The potential for using dyes or artificially manipulating turbidity as a cost-effective method of cormorant control has yet to be proven.

4.1.2.15 Dogs

Trained dogs, such as border collies, can be used to scare birds away from a site. The efficacy of such an approach for deterring cormorants is not known.

4.1.2.16 Overview of visual deterrents

Efficacy

As with auditory deterrents, the effectiveness of visual deterrents varies with the device chosen, the method and timing of use, the size of the site and the availability of alternative foraging sites for the birds. Typically, fixed visual deterrents are only thought to have an effective range of up to about 200 m. As such, these techniques will be of limited, if any, use on river systems, coastal areas or larger stillwater sites, with the possible exception of localised predation 'hot spots', or in the vicinity of fishing gear.

All visual deterrents, particularly static ones, are subject to habituation by cormorants, and hence they are generally of short-term benefit (typically days to weeks) as the birds eventually get used to them, unless they are moved regularly and used in conjunction with other deterrents. The effectiveness of visual deterrents also depends on their visibility and how real a threat they are perceived to present: visual scarers are most effective if they are life-like, move and possess biological significance, or if they are associated directly with a real threat.

Disturbance by humans is regarded as the most effective visual deterrent, but cormorants can learn to feed during even short periods when humans are absent (e.g. meal breaks), especially where feeding success can be assured (e.g. at heavily-stocked fish ponds). Studies suggest that human effigies and raptor models may be more consistently effective and longer lasting as bird deterrents than kites, balloons and flags.

Practicality

Visual deterrent devices are used widely for a range of bird scaring purposes and most are readily available, easy to deploy and simple to use. Such deterrents thus rate highly from the viewpoint of practicality for many sites. Regulations may cover the use of some visual deterrent devices (e.g. lasers, model aircraft, flashing lights) and/or restrict their operation in sensitive areas such as airfields. Local guidance and necessary approvals should always be sought prior to using such devices. For more expensive visual deterrents (e.g. automated inflatable scarecrows), security should be considered carefully to safeguard the devices against theft or vandalism.

Costs

The costs of visual deterrents vary widely, depending on the complexity of the device itself and the level of human participation required. Simple static scarecrows and flags are usually constructed from inexpensive materials, while automated devices are relatively more expensive, depending on their level of sophistication, and devices such as some lasers can be costly. Commercial bird-scaring laser guns can be very expensive, but cheaper, hand-held laser pointers can be just as effective. Laser licensing and training costs must also be taken into account.

For many visual scarers, manpower costs are low, being mainly confined to initial deployment, periodic checking and, perhaps, movement around a site. However, the cost of using dedicated staff for 'human disturbance', or to operate a laser gun, may be considerable, particularly if required on a regular basis. Manpower costs might be reduced where incidental human presence at a site can be arranged or where volunteers or local stakeholder groups participate (see Case Study No. 4 — Slovenia).

Acceptability

The use of visual deterrents for scaring birds is widely recognised and, since their impact is usually very localised and non-lethal, they have a high level of acceptability and are generally not a matter of public concern. However, such devices are not selective and so may impact on other wildlife, and this should be taken into account. Some visual deterrents may not be acceptable in certain locations (e.g. flashing lights or perhaps bird corpses near residential areas, model aircraft and kites near airfields, or lasers near roads). Particular care is also necessary with all uses of lasers even where it is legal to use them.

4.1.3 Chemical deterrents

Chemical taste repellents are quite widely used for reducing the impact of pest birds in agriculture and forestry, as well as a means of deterring birds from perching on buildings. Such techniques have not been widely tested against fish-eating birds, but they may have some potential. Chemical repellents fall into two broad categories: primary repellents and secondary repellents. Primary repellents are avoided upon first exposure because they smell or taste offensive or cause irritation. Secondary repellents are not immediately offensive, but they cause illness or an unpleasant experience following ingestion. The bird links this negative experience to the taste of the treated food and will avoid this food in future. Due to their toxicity, and concerns about adverse effects on the environment, the use of chemical repellents is usually tightly regulated.

A number of chemicals (such as methyl anthranilate, dimethyl anthranilate, cinnamide, anthraquinone, adirachtin, 4-aminopyridine, methiocarb, and caffeine) have been proven as effective deterrents against different bird species. Some of these substances are registered as bird repellents in the USA, but they are not authorised for use in many other countries and few chemicals are believed to be registered for use in Europe. In addition, not all of them have been tested on cormorants.

Chemical repellents are generally most effective on surfaces or indoors, and animals usually habituate to smells quickly. For these reasons they are difficult to apply effectively outdoors, especially in large areas such as fish growing areas. In addition, most are relatively expensive. Furthermore, methyl anthranilate can be toxic to aquatic fauna and may not be sprayed near water bodies unless it is in a special formulation designed for this purpose.

Despite these drawbacks, chemical repellents have been used effectively to deter birds, including cormorants, from large areas, such as airports. The repellents are typically applied using a fogger machine; in some places the foggers have been attached to motion detectors so that they only spray chemical when flocks of birds approach, to avoid habituation and to reduce costs. The potential of applying repellents as a very thin surface film, in order to deter birds from entering particular water bodies, has also been investigated. Research in this area is believed to be ongoing.

Most bird deterrent chemicals do not impact mammals, and mammal deterrents such as hot-sauce (capsaicin) are ineffective against birds due to differences in their nervous systems. Nevertheless, many people dislike the smell of some of these chemicals, especially the sickly-sweet, grape-like smell of methyl anthranilate, so it should not be sprayed near settlements.

Trials have also demonstrated that conditioned taste aversion (a subconscious association between taste and a feeling of illness experienced after ingesting treated food) can be successfully induced in captive cormorants fed on dead fish dosed with carbachol. Individual birds learned to avoid Brown Trout (*Salmo trutta*), the treated species, but continued to eat other species of fish, and this effect lasted for seven months - the entire duration of the trial — without reinforcement.

Clearly, applying such a technique in the wild presents significant difficulties and would not be appropriate at sites on cormorant migration routes, due to the extensive turnover of the birds. However, it might have potential at some sites where birds demonstrate local feeding-site fidelity and where there is a need to protect a particular species of fish. Considerable further work would be required to develop an effective method for delivering the chemical to the target birds.

Because of the complexity and drawbacks of using chemical repellents for deterring birds outdoors, and the associated controls on their use, it is important that all aspects, potential repercussions and regulations are considered carefully before commencing any programme to use them against cormorants.

4.1.3.1 Overview of chemical deterrents

Efficacy

The efficacy of chemical deterrents will be highly variable depending on which chemical is used on which species and on the mode of delivery. While proven to be effective for captive cormorants fed on dead fish, safe and effective chemical repellents have not been developed to a level where they can be recommended for use in fishery or aquaculture applications at the current time.

Practicality

Chemical deterrents are most effective on surfaces and in enclosures, and they are more difficult to apply outdoors. The practicalities of administering repellents to cormorants and/or water bodies require considerable further work before the technique could be recommended for wider use.

Costs

Most chemical deterrents are expensive, although fogging machines can reduce the amount of chemical needed. However, in large areas the costs can be prohibitive.

Acceptability

Chemical deterrents that do not harm (but only deter) wildlife are generally very acceptable as a non-lethal method to stakeholders. However, the use of potentially harmful chemicals in the environment does raise acceptability issues and requires mechanisms to ensure that substances could be administered to cormorants without a risk of lethal poisoning, or threatening other bird and other, non-target wildlife species. Thus, any possible human health or environmental implications would have to be taken into account to ensure any such techniques did not have adverse effects.

4.2 Protecting The Fish — Exclusion Techniques

These tools involve excluding the birds from the fish. Not surprisingly, the techniques work best when fish are concentrated in relatively small areas. Thus, they are ideal for land-based ponds or raceway fish farms where netting enclosures can be fixed permanently. At other sites, such as off-shore fish farm cages, anti-predator netting can be hung in curtains underwater to prevent diving birds reaching fish stock in the mesh 'bag' of the cage. In larger water bodies, complete exclusion is far more difficult and may well be impractical. At such sites it may be possible to take advantage of the fact that cormorants generally require quite long distances for take-off and landing. By positioning wires or ropes across waters it may be possible to make it difficult, or impossible, for cormorants to land on, or take off from, the water's surface. Although certain spacings of these wires appear to be more effective than others, there is considerable scope for experimentation at fishery sites.

4.2.1 Netting enclosures

Complete enclosure of a site with netting is undoubtedly the most effective option for preventing predation by fish-eating birds,

Netting enclosures at fish farms.
Photos courtesy of Bruno Broughton and Thomas Keller.

including cormorants. Properly designed, such netting enclosures can provide people with uninhibited access to enclosed waters, allowing fishery management or aquaculture tasks to be undertaken. Relatively inexpensive, lightweight netting is now available and, secured to frames or supported by overhead wires, this has enabled the enclosure of water bodies extending to several hectares and the protection of long lengths of linear waterways (extending to several km) at some fish farm sites, for example in Italy. Such enclosures are widely used to protect fish farm sites in many countries, although costs can still be substantial. There are commercial companies that sell and install complete enclosure systems for such sites.

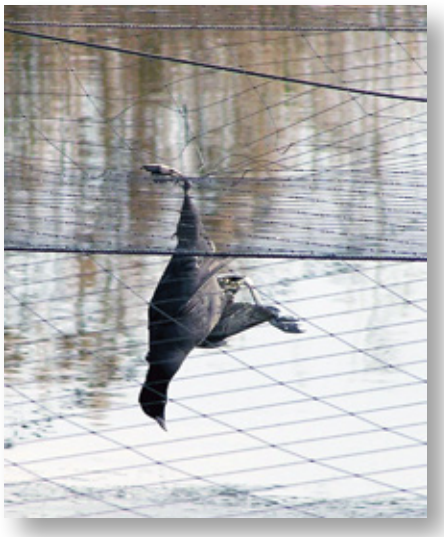
Large-scale netting enclosures in the Commachio lagoons, Italy.
Photos courtesy of Stefano Volponi.

Full enclosures also provide secondary benefits in helping to reduce or prevent predation from non-avian predators such as American Mink (*Mustela vison*) or European Otter (*Lutra lutra*). However, experience has shown that small carnivores can gnaw through netting or slide under it if it is not held down securely. Thus, more robust wire netting might be required close to ground level where losses to such predators are a particular problem.

A study in Israel investigated the problem of birds becoming entangled and dying in netting enclosures over fish ponds. The results showed that birds are more likely to become entangled and die in thin, colourless or light-coloured netting with large mesh size; monofilament fishing nets were especially dangerous. In addition, poorly maintained netting, with many holes and tears, could turn an entire fish pond into a trap where birds entered but couldn't find a way out. These birds lived in the ponds and actually consumed more fish than birds at unprotected ponds. The conclusions of this study were used to establish a set of guidelines in Israel for fish pond netting that included the provisions that the netting must be of a small mesh size (5–7 cm), made of thick, dark material and not of monofilament fishing net. The netting must also be well maintained and any holes and tears repaired.

There are a number of general considerations regarding the effective deployment and use of netting enclosures:

- Netting should be sufficiently robust to withstand wind and snow/ice accumulation and to withstand degradation by



Birds trapped in netting.
Photos courtesy of Thomas Keller and Stefano Volponi.

weathering (e.g. exposure to sunlight). More expensive, robust netting may be more cost effective than cheaper nets when the frequency and cost of repair and/or replacement is considered, and these will also be more visible to birds.

- Netting should be strung reasonably tightly to prevent the weight of any birds standing on it from causing it to sag. Where nets are strung close to the water surface, this additional weight could allow birds direct contact with the fish. However, nets should not be strung too tightly: research in Israel has demonstrated that netting that is too taut tends to entangle more birds (probably as a consequence of its reduced visibility compared with a slightly sagging net that moves a bit in the wind).
- Netting should be of a fairly small mesh size (5 to 7 cm mesh width), to provide complete exclusion of all birds, although larger mesh sizes (15 to 50 cm) can be sufficient for larger birds such as cormorants. Dark-coloured material is preferred to ensure maximum visibility to birds. Very thin monofilament fish nets must be avoided to prevent possible entanglement of birds.
- Netting should be checked regularly and maintained as necessary. Poorly maintained nets may allow predators access to the water but prevent them from getting out, thus potentially increasing fish losses.

The use of full netting enclosures may be largely restricted to aquaculture facilities and stock ponds, and is likely to be incompatible with angling waters. However, it might be realistic to use the technique at some smaller recreational fishery sites as a temporary measure, perhaps in winter when bird numbers tend to be highest and when angler visits are often substantially reduced, assuming that the nets could be installed and removed relatively quickly. For example, two parallel wires fixed around the circumference of a pond, one above head height and the other close to the ground, would allow sheet netting to be strung over the pond and secured with simple nylon 'S' hooks (i.e. stretched over the upper wire and secured to the lower wire).

Partial netting enclosures have also been used with some success. A survey of hatchery managers in

Vertical netting across recreational fishery, UK.
Photo courtesy of John Black.

Floating anti-predator net over fish farm pond, Israel.
Photo courtesy of Simon Nemtzov.

the USA found that netting placed over fishery ponds (top screens only) was one of the most effective methods of deterring fish predators. In Germany, small mesh covers (mesh sizes <20 cm) were placed over just part of a large pond, covering about 10% of the water surface. These served as a refuge area that fish could enter during the day when cormorants were feeding. Here, the fish (Carp) were provided with supplementary food in the protected part of the pond, but they used the whole water body for feeding at night. A similar approach has been used in Italy, where sheets of netting have also been hung vertically, close to the water surface and across channels at extensive fish farm sites to interfere with the ability of cormorants to take off and land. Reportedly, these have proved effective, although there is a risk that other bird species can become entangled in the netting.

In Israel, floating cages of approximately 10 m diameter have also been located in fish farm ponds over the spot where fish congregate near automatic, pellet feeders. This prevents birds from attacking these large concentrations of fish near the surface.

Underwater netting

Submerged netting enclosures can also be used to protect fish held in floating fish cages from diving predators, particularly cormorants. On the Scottish west coast, underwater anti-predator nets are commonly placed around fish farm cages to protect fish stocks from seals and fish-eating birds, including cormorants. There is no evidence that cormorants tear holes in the netting, nor that they take fish directly from farm cages. To do this, such holes would need to be large enough to enable stock to escape. However, cormorants can cause damage to fish by poking their beaks through the nets. They have large, powerful beaks with a formidable hook and are capable of wounding or killing fish.

In order to prevent cormorants reaching the fish held in cages, underwater nets (commonly of 10 cm square mesh) are suspended below the cages, outside the net bag holding the fish. These nets protect all four sides and the bottom. At some sites, weighted curtains of net are suspended from the cage superstructure but these do not protect the bottom of the cage. Loose netting is more likely to ensnare birds and fish, so netting needs to be taut. It should also be checked regularly and maintained, and it will therefore need to be fixed so that it can be raised easily to the surface. A separate sheet

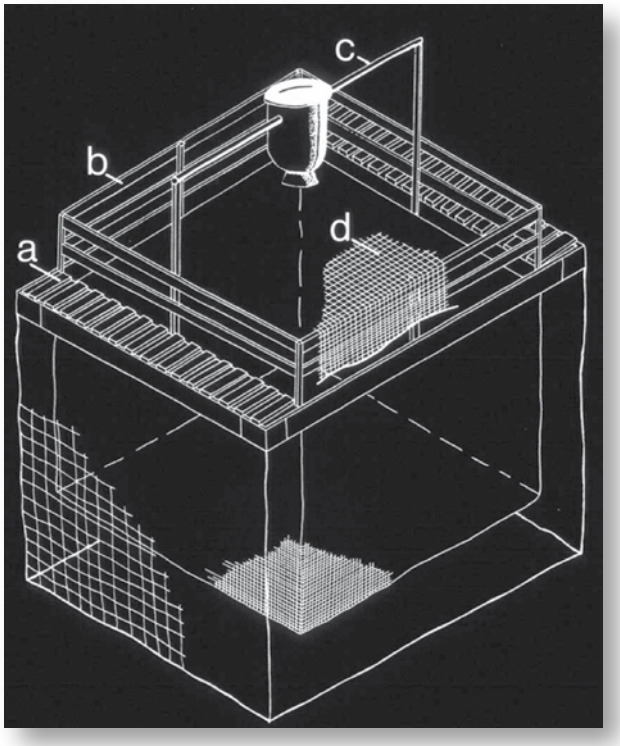
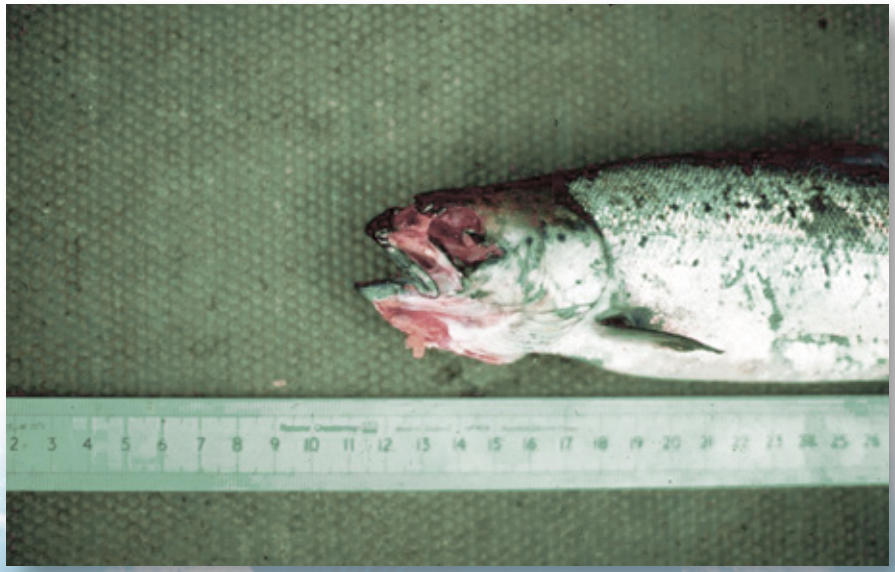


Diagram of fish cage showing (a) walkway, (b) top hand-rail, (c) feeder pole and (d) top netting. Underwater anti-predator netting can be seen below the water surface offering protection to the fine-meshed net which holds the fish stock.
Figure courtesy of Dave Carss.

of netting stretched over the top of the fish cage will also be required to keep predators from entering the cage itself.

There is evidence that such underwater anti-predator netting reduces the numbers of fish injured or killed by cormorants in cages, and also that clean nets are less effective at protecting fish than are nets fouled with seaweed. However, underwater anti-predator nets are not totally effective, even when installed and maintained correctly. This is because common cage design usually only allows for a maximum of 1 m between the cage net and the anti-predator net. Thus, underwater — possibly at a depth of several metres — the nets can be relatively easily pushed together by water movement, potentially allowing birds or other predators to access the fish.

Trials have also been conducted in Denmark to evaluate the potential of using 'barrel' nets inside coastal pound nets (a commonly-used fishing technique). The barrel nets were located in the central fish capture area of the pound net known as 'the pot'. They were mounted vertically from the bottom to 0.5 m above the water surface in the pot and a variety of configurations were tested. The barrel nets were intended to hinder cormorant swimming and foraging behaviour and make it unprofitable for cormorants to forage in the pound nets; they did not prevent birds from entering the pound nets themselves. The presence of the barrel nets was shown to increase cormorant foraging costs (e.g. number of dives per fish caught), to reduce the amount of time birds spent inside the net, and also to reduce the number of cormorant visits to the net. However, while the barrel nets were designed to allow unhindered access for



Salmon smolt killed by cormorant beak through fish cage netting.
Photo courtesy of Dave Carss.

'Cormorants can cause damage to fish by poking their beaks through the nets. They are capable of wounding or killing fish'

fish, fishermen have indicated that their presence has a negative impact on catches. In light of this, and the cost of installation, the technique has not been widely adopted. Other similar underwater netting deterrents are reported to have been used to try to exclude cormorants from fishing gear in Finland.

4.2.2 Using 'wires'

The word 'wires' is used here as a generic term that could also include cords, ropes or tapes. Wiring systems provide a cheaper alternative to complete enclosure with netting.

Fish-eating birds searching for feeding opportunities can be deterred from utilising waters protected by wires as these affect the birds' ability to land, feed and take off. For example, cormorants require 8–12 m of open water in their take-off run. There are various ways in which wires can be deployed in order to deter fish-eating birds from foraging at a site. Commonly, wires are held taut above the water surface fixed securely to posts set into the banks, but ropes can also be floated on the water surface, and a wide range of spacing and deployment patterns can be used to facilitate other uses of the water bodies. Options are discussed in greater detail below.

Trials conducted in a number of countries have clearly demonstrated that the deployment of wires can substantially reduce cormorant impacts on fish (see Case Study No. 5). However, results have been very variable, and in some trials there has been no apparent benefit. Furthermore, what has worked for cormorants has not necessarily worked for other bird species.

A number of factors have been shown to affect the efficacy of wiring systems. Studies in the Netherlands and the USA indicated that wiring exclusion devices are more effective at deterring large flocks of cormorants but that single birds learned to feed at the ponds 'protected' by wires. Further, the effectiveness of wires has been shown to depend upon alternative foraging sites being available. For example, in a trial at gravel pits in the UK, cormorants avoided a pond protected by wires (2 m spacing) but regularly used an adjacent pond of the same size and similar fish stock composition where protection was absent. However, when the second pool was also wired, cormorants resumed fishing on the original pond, despite the presence of wires there.

As with most deterrents, birds can become habituated to the presence of wires and may learn to evade them, perhaps even specialising at feeding on wired ponds. There is evidence that some birds can avoid wires by walking into the water and under the wires from the adjoining bank, while others have been observed hovering above the water before dropping into it between wires. Cormorants have also been shown to use starting positions that allow completion of their take-off runs between wires. Birds that learn to land, feed and take off on wired ponds may attract others to the site, so it may be necessary to use a combination of deterrent measures to counteract this.

It has been shown that the closer wires are spaced, the more effective they are at obstructing birds from landing and taking off. Thus, wires should ideally be spaced as closely as possible within the constraints of cost and practicality. Some trials have indicated that parallel wires set 20 m apart can be effective in reducing cormorant predation, but other studies have found this ineffective, with birds learning to move easily between wires with such spacing. Most trials have been conducted with wires spaced more closely than this. For example, see Case Study No. 5.

In addition, experimental trials conducted at commercial fish ponds in Hong Kong in the winter of 2001–02 investigated the effectiveness of wires spaced at 5 m and 10 m intervals, and suspended 5 m above the water surface. Eighteen ponds were used in the trial, from an extensive area of ponds, with the trial ponds allocated into six groups of three, with each group containing a pond with 5 m wiring, one with 10 m wiring and a control pond (no wires). Ponds were allocated to groups so that the three ponds within each group were broadly similar with respect to the extent of cormorant utilisation and their location within the site.

The results demonstrated that installing wires significantly reduced the number of cormorant-visits to the experimental ponds. However, cormorant visits to all the trial ponds, including the control ponds, were lower following the installation of the wiring. Essentially, the numbers of cormorants utilising the overall study area decreased, most probably since the birds had abundant alternative feeding sites

nearby, away from the study area. A median reduction in cormorant visits of 99.5% and 98.5% was recorded in the ponds with wires spaced at 5 m and 10 m intervals respectively, while there was also a smaller median reduction in cormorant visits at the control ponds of 48.4%. The decrease in cormorant visits was significantly greater in the wired ponds (both 5 m and 10 m) compared to the controls, but there was no significant difference in the number of cormorant visits between the 5 m and 10 m wiring.

Other trials with wires set at 10 m spacing have produced more variable results and, in general, more success has been achieved with wires spaced 4–8 m apart. Spacing of 7.5 m or less is generally recommended, although spacing may need to be balanced with any potential impacts on fish husbandry practices.

The height of the wires above a pond is also believed to affect their efficacy. Reports indicate that wires suspended 30–40 cm above the water surface are most effective, as at this height the wires interfere with a cormorant's take-off run. If set lower the cormorant is able to 'jump' over the wires; if set higher, the cormorant can complete its take-off run underneath the wires. Dependent on the span of water to be covered, wires may have to be supported by poles located in or around the pond to maintain the required elevation. However, other practicalities may require alternative deployment arrangements. For example, it may be necessary to deploy wires at greater heights in order to facilitate access to the water (e.g. to carry out fishery management or fish farming activities). Alternatively wires might be more conveniently strung close to the water surface supported by floats.

Floating ropes provide another 'wiring' option for deterring cormorants from water bodies. Trials on catfish ponds in the USA using parallel lines of thick (9.5 mm diameter) yellow rope, spaced at 15–17 m intervals with foam floats attached, reduced the numbers of Double-crested Cormorants using the ponds by 95% for the 3–5 weeks that the ropes were in place. However, towards the end of the trial, some cormorants appeared to have learned how to negotiate the ropes. Such floating rope deterrents have the advantage that they can be deployed and removed quickly and require no permanent fixing points. This could thus be another measure that would be suitable for use at stock ponds, although there is also scope to consider their use on small recreational fisheries, perhaps on a temporary basis (e.g. at times of peak predation or when there are few angler visits).

Wires should be made as visible as possible to incoming birds, both to act as a deterrent and to prevent the deaths of cormorants or other birds through collision. Steel wires may offer the most permanent and durable option. However, coloured nylon cord is also commonly used for overhead 'wires' because this is relatively cheap, durable and easy to deploy. For example, coloured plastic tape (4 mm width and spaced at 20 m intervals) was successfully used to deter cormorants from a 3.5 ha gravel pit located in a core cormorant breeding area close to the River Danube upstream of Vienna. The tape took around two hours to deploy and ducks continued to utilise the site.

Parachute cord is another practical alternative, especially as its elasticity enables it to be drawn taut over a pond. Bird deterrent tapes are also available for

Wiring configurations at fish ponds, Germany. Photos courtesy of Thomas Keller.

purchase and are highly visible, although these degrade over time and may be more suitable as short-term measures. Attaching coloured 'flags', reflective tape or CD discs at appropriate intervals can readily enhance the visibility of wires. Once installed, wiring systems require little upkeep, other than maintaining proper tension and replacing occasional broken wires. For this reason, it is better to use multiple single cords to span a pool, as these can be easily replaced, rather than a continuous cord looped from bank to bank, where a single break might cause the whole network to collapse.

Various wire configurations have been used in trials, but no optimum design has been identified. It appears that spacing of the wires is probably more critical than the arrangement used. Configuration options have included parallel lines, regular rectangular grid patterns (the latter techniques are most commonly used) and irregular zig-zag patterns. An alternative 'circus-tent' construction has also proved effective in the Netherlands, where wires were strung from the top of a 10 m post in the middle of a pond to the bank, like the spokes of a wheel, with wire spacing at the pond edges of 14–15 m. This had advantages over a grid system by reducing obstacles to boat operation. This arrangement caused less hindrance to cormorant take-off runs, but it appeared to be more effective than a grid arrangement at deterring birds from landing.

At one fish-rearing site in the UK, parallel parachute cords stretched tautly across a pond at approximately 30 cm intervals completely prevented cormorant predation, but allowed ducks to fly onto the pond successfully.

Parallel cords protecting a fish-rearing pond, UK.
Photo courtesy of Bruno Broughton.

Overhead wires have been employed with some success to deter cormorants in a number of countries. They have mainly been used at fish-farming sites containing small ponds of uniform shape, rather than on recreational fisheries where the size of the water bodies and their more complex shapes can present insurmountable difficulties. However, overhead wires have been deployed in conjunction with brightly coloured warning wires and tapes to protect small rivers and other linear water bodies in some countries, including Austria and Italy.

In Slovenia, agricultural string (used in hop growing) has been stretched in a zig-zag pattern over pools in small streams — known to be predation 'hot spots' — where it proved both cheap and successful at protecting fish in these environments. However, the technique required considerable maintenance to remove vegetation debris falling from bankside trees.

In Austria, several upland river sections were protected with 3–4 mm diameter wires in order to prevent cormorants reaching their prey, principally Grayling (*Thymallus thymallus*). The wired sections extended up to some

hundred metres of river length, the wires being attached between the trunks of trees or bushes on both banks. The distance between the wires — generally less than 10 m — and the water surface was chosen carefully to enable sporting activities like canoeing or rafting to continue. To avoid injuries to cormorants and other birds that sometimes do not recognise wires, conspicuous warning tapes were also attached to the wires.

The wires were kept in place between October and March/April, the period when cormorants are present. Anglers inspected some of the wired river sections on a daily basis and reported that they had not seen any cormorants entering these either by flying in or by diving and swimming into the sections from adjacent areas. Other bird and fish ecology monitoring is ongoing in the wired and adjacent, unwired sections. Interim results show that despite some damage to the wires — for example, as a consequence of flooding and vandalism — the density of some fish species was higher in the covered sections.

Wires with warning tapes across a river, Austria.
Photo courtesy of Reinhard Haunschmid.

Similar techniques have been used successfully to protect wild trout and Grayling on the upper River Tevere in Italy. However, they were considered to be visually intrusive by some walkers and tourists, and local wild boar hunters thought that the wires caused the animals to abandon their usual tracks, making them harder to kill.

4.2.3 Floating plastic balls

Covering a pond with floating plastic balls has been used as a very effective method of keeping birds from landing on small bodies of water. This method has been especially useful for keeping waterbirds away from effluent ponds or bodies holding toxic water where the birds may be harmed. Due to the relatively high cost of this method, it may not be suitable for fish breeding ponds unless the ponds are small or the fish are especially valuable (such as brood stock or ornamental fish).

4.2.4 Facility design and construction

When establishing new aquaculture facilities or stock ponds, careful design of the site can greatly help the incorporation of measures for deterring predators from the outset. For example, fish farms for salmonid production in Denmark were designed in a way that allowed wires to be easily incorporated. Nets and wires can be used on square or rectangular ponds far more easily than on round or oval

ponds, or those of irregular outline. Where anti-predator nets are to be used over man-made ponds, the water bodies could be designed with dimensions that enable standard-sized nets to be deployed over them. Ideally, new aquaculture facilities should not be constructed in known cormorant flyways.

4.2.5 Overview of exclusion techniques

Efficacy

Nets and wires are readily available and can provide reliable, long-term, cost-effective options for removing or reducing cormorant predation at a site; their effectiveness depends on proper installation and maintenance. Indeed, netting enclosures that completely enclose a site provide the only reliable means of excluding all birds (and other predators) from a site. In contrast, 'wires' typically deter birds from using sites, but they are unlikely to exclude them altogether. Nonetheless, wires can still be very effective at reducing fish losses. The efficacy of such structures varies according to the system chosen (particularly the spacing of the wires) and can be particularly effective where cormorants have access to other feeding areas in reasonably close proximity. Efficacy may also decrease over time as birds learn to avoid the wires. It may therefore be necessary to use other deterrents in conjunction with wiring.

Practicality

The applicability of enclosure techniques will inevitably be constrained by practical considerations and costs. In practice, netting exclusion structures are likely to be restricted to protecting small areas of water and particularly valuable fish stocks, such as those found at fish farm sites. Permanent wiring systems are probably more widely applicable and can be used for protecting larger fish farms and stock ponds, but they are probably also more cost-effective at relatively small sites. Both nets and wires will be inappropriate at most fishery sites where the size of these water bodies will be a major constraint.

In addition, aesthetic considerations and the problem of entangling fishing lines will also be problems, although some types of angling might still be possible in the open 'lanes' between wires if these were of sufficient width. However, wiring systems can be deployed on a temporary basis and so might still offer the potential for short-term, seasonal protection at such sites.

Costs

The cost of installing a full netting enclosure at a site will be high and this will need to be balanced against the level of protection required and the value of the stock being protected. In contrast, wire deterrents can be deployed relatively cheaply and need little labour to maintain, but like netting they need to be checked regularly for damage that will otherwise be exploited by birds. For both techniques, the potential durability and long-term efficacy of the measures need to be weighed against the losses of fish to cormorants, the inconvenience to those requiring access to the water, such as anglers or farm managers, and the costs of alternative deterrent measures that may require substantial ongoing expenditure. It should also be borne in mind that less durable, cheaper, temporary structures might also be considered at some sites, such as stock ponds and, perhaps, small fishery waters.

Acceptability

The use of exclusion techniques is widely recognised, highly effective and has a high level of acceptability in most instances. Such measures are mainly used locally at fish farm businesses to protect relatively small sites containing valuable stock. Generally, they are unlikely to attract criticism or comment from the general public. However, aesthetic concerns might arise where exclusion devices are used at natural sites and reduce the perceived amenity value. The use of netting will clearly not be appropriate at sites of designated nature conservation status, particularly where this is in respect of other bird species. It should be borne in mind that the deployment of such structures will also affect the ability of waterfowl and other wildlife to access protected sites. Further, nets and wires can result in birds getting entangled and damaged — especially where such structures are poorly maintained or deployed in a manner that increases the risk of accidental capture (e.g. low visibility, fine mesh).

4.3 Reducing Fish Availability To Cormorants — Fish Stock Management Techniques

The idea behind this selection of tools relies on the fact that cormorants, like all predators, need to make a number of choices when selecting where to feed. Although whether cormorants are actively 'choosing' where to forage is open to debate, a number of issues must

be balanced if birds are to obtain their daily food requirements. These will include the body state of the bird (whether it is losing or gaining weight), environmental conditions (more food/energy is required during colder/wetter periods), the state of the annual cycle (migration periods, breeding season, over-wintering) and the distances between roosts or colonies and feeding sites. Foraging site choice is also dependent on the 'availability' of suitable areas and both the number of potential feeding sites and their 'quality'. In simple terms, 'high-quality' foraging sites will be those that offer risk-free, undisturbed access and feeding, with good supplies of relatively easy-to-catch fish.

While many of the techniques described already in this Toolbox have involved the deterrence or exclusion of cormorants, there are also a number of ways in which cormorant-fishery conflicts might be influenced through the management of the fish stocks themselves. Such techniques attempt to alter the 'quality' of the foraging opportunities available to cormorants by trying to make fish less easy for the birds to catch. The underlying principle is that if fish are difficult to catch, then the birds may choose to feed on other waters where the fishing is easier. For example, where fishery managers have control over fish stocking regimes, there are several options that might reduce fish losses and make sites less attractive to foraging cormorants.

4.3.1 Timing of stocking

One simple means of reducing cormorant predation is to time the introduction of fish so as to minimise the likelihood of encounter between birds and fish. For example, this might involve delaying stocking to reduce the availability of fish during the period of peak cormorant numbers, or draining and removing fish from more vulnerable fish farm ponds prior to the arrival of cormorants. Delaying stocking can be appropriate in the case of recreational put-and-take trout fisheries, particularly where they mainly operate from spring through to autumn and where cormorant numbers are highest in winter. In such instances, it would be advisable to stock fish as late as possible prior to the start of the fishing season and to 'run down' the numbers of fish at the end of the season to avoid leaving high densities of fish to over-winter. However, the viability of this approach will be limited where fisheries remain open, or where cormorants are present in substantial numbers throughout the year.

4.3.2 Frequency and location of stocking

The frequency and location of stocking can also be managed to reduce the chance of large aggregations of recently released, naïve fish attracting predators. Newly-stocked fish can be at a significant predation disadvantage because anti-predator behaviour are learned during a fish's lifetime as well as through instinct. Fish from a hatchery or fish farm are likely to have poor anti-predator behaviour. They may have lived in artificial environments with little or no cover and they might have little experience of avoiding predators. Furthermore, prior to stocking all fish will have undergone some stress in handling and/or transport. Once released into a new environment, often where they are no longer fed artificially, stocked fish thus need to learn quickly how to survive, perhaps foraging on new prey species, learning to use cover and to avoid a range of new predators.

Where fish are stocked regularly, it is advisable to 'trickle' stock fish at regular intervals rather than release larger batches of fish less frequently. Furthermore, stocking fish at a number of locations around the fishery margins, for example from a boat, or deploying scaring devices at stocking sites, may help to avoid predators aggregating at specific release points. It should be recognised that increasing the frequency of stocking and the number of release sites will entail additional transportation and handling costs, and so these management options may be more appropriate at larger fisheries (where economies of scale may apply) or for those that have their own rearing or on-site fish holding facilities, such as tanks or floating cages.

4.3.3 Regulating fish density

At aquaculture sites there may also be opportunities for regulating fish densities during sensitive periods. For example, pond owners in Germany can reduce the fish density in some Carp ponds at times of increased threat from cormorants. However, such stock density manipulation is not feasible at most fishery sites, and anglers at recreational fisheries would probably not accept lower

fish densities during the main cormorant feeding period.

While of limited applicability, this simple technique can be an effective short-term measure in aquaculture and at some recreational fishery sites that are routinely stocked, and associated costs can be relatively low.

4.3.4 Size at stocking

A further option for reducing losses to predators in some situations is to stock with larger fish. This is because above a certain size, fish become less vulnerable to capture and, ultimately, too large to be swallowed by cormorants. The size at which fish become significantly less vulnerable will vary for different species of fish depending on factors such as their body shape. The potential for stocking larger fish will be more applicable to fisheries that are dependant on regular introductions of fish, such as put-and-take trout fisheries, than to 'natural' fisheries.

This method has proved fairly successful at trout fisheries in the UK where, after stocking with relatively large trout, cormorants consumed fewer stocked fish and either had to switch their diet to resident 'coarse' fish (i.e. non-salmonid) populations or move to other sites. Both Rutland Water and Grafham Water, two of the best known, large trout stillwater reservoirs in England, have followed such a successful fish stock management programme in recent years. Although the minimum size of the fish stocked has been increased from about 1lb to 1.4lb (0.45–0.64 kg), with a high proportion of fish above 2lb (0.91 kg), the increased rearing costs are reported to have been covered by the better catch return rates and reduced levels of scarring damage caused by cormorants. The size of the cormorant winter roost and breeding populations near Grafham has fallen since these measures were introduced, quite probably reflecting changes in local prey availability at these fisheries. The stocking of larger trout is now routine at put-and-take trout fisheries in the UK.

Cormorant damage to rainbow trout.
Photo of unknown origin (UK).

The extent to which fish are damaged by cormorant capture (and subsequent escape) also appears to be influenced by fish size. It seems reasonable to assume that the chances of a fish escaping from a cormorant, once grasped in the bill of the bird, will be relatively slight for smaller fish, but will increase progressively as the fish gets larger up to the point where the fish becomes too large for the cormorant to catch. Investigations at a stillwater trout fishery in the UK support this. The incidence of fish bearing wounds consistent with 'handling' by cormorants was low among the smaller (25–35 cm) trout stocked (although return rates of this size group were poor due to higher losses), but much higher among fish of 35–45 cm in length. Above this size, the incidence of cormorant marks on the fish was low.

Specimen-sized Carp.
Photos courtesy of Bruno Broughton.

However, this approach has limited use for many freshwater fisheries, especially those on rivers. Natural, sustainable fisheries cannot be established if stock regimes are constantly being manipulated, and fisheries biologists in many countries do not favour the stocking of unusually large fish to enhance natural fish populations. However, not all anglers may share this view. Fish of a size that are too big for cormorants to eat do not occur naturally in many species and are not available commercially in others.

Saxony fish farm Carp showing cormorant damage.
Photo courtesy of INTERCAFE.

The possible exception is stocking recreational fisheries with Carp of 2lb (0.91 kg) and larger, but this is not applicable to river fisheries (in the UK at least) and is regarded by many people as inappropriate for many stillwater fisheries, on environmental grounds. It is widely recognised, however, that the marked development of Carp fishing in the UK in recent years has been partly influenced by the vulnerability of smaller, native freshwater fish species to cormorant predation.

A variation on this approach is also used in aquaculture, with the rapid production of larger, one-year old (>100 g) and two-year old (>700 g) Carp through supplementary feeding, a technique tested successfully in Saxony (eastern Germany). The aim here is to encourage the Carp to grow more quickly, so that in their second summer (when they would otherwise be of optimal size for cormorants under 'normal' growth conditions) the fish are generally too big to be consumed by the birds.

Similarly, at cyprinid farms and recreational fisheries in the UK, the aim is to grow Carp up to or over 1 kg in weight during or towards the end of their second summer. At this and greater weights, anti-cormorant measures can be withdrawn in the knowledge that they will no longer be required to protect the fish.

4.3.5 Species vulnerability

Prey vulnerability is known to vary for different fish species as a consequence of factors such as fish size, body shape, behaviour

and the type of habitat they prefer. Thus, for example, species with larger potential size (e.g. Carp and Trout), deeper bodied fish (e.g. Common Bream, *Abramis brama*) and those that make extensive use of habitat features, where available (e.g. Tench, *Tinca tinca*) are likely to be less vulnerable to cormorants. It also appears that Brown Trout are relatively more vulnerable to cormorant predation than the non-indigenous Rainbow Trout (*Oncorhynchus mykiss*). While wider biodiversity issues also need to be borne in mind, such differences may have some application for fishery managers when considering the cost-effectiveness of different stocking policies.

Alternative prey species — small Roach *(Rutilus rutilus)* and Perch *(Perca fluviatilis)*. Photo courtesy of Bruno Broughton.

4.3.6 'Buffer' species

The idea of managing fish stocks to enhance or introduce alternative, less valuable prey species, either in the 'target' fishery or in nearby bodies of water, has been proposed as a way of reducing cormorant impact on more valuable species. This is unlikely to be appropriate for rivers and costs may be prohibitive. However, the presence of Cyprinid (Carp family) fish at a stillwater trout fishery, for example, does reduce the losses of trout. It is not clear whether or not higher overall fish densities, due to stocking buffer prey alongside commercial species, may serve as an increased attraction to predators. If so, the stocking of buffer prey at alternative sites away from important fisheries may be a preferred option, although an increase in the total density of prey in an area might also attract more predators to the area as a whole, with the added danger that fish might habituate to an area and continue to forage there after any spare buffer fish have been consumed.

Investigations in Australia indicated that fish losses to cormorants were lower in farm dams (used mainly for irrigation) where these also contained resident populations of crustaceans (crayfish). It was therefore suggested that stocking farm dams with crayfish could be used as a method to buffer cormorant impact and reduce fish losses.

The natural availability of different fish species in a community can also have this buffering effect: if a proportion of the birds' diet comprises fish species of little recreational or economic value, this will reduce the impacts on more desirable or valuable species. On natural or semi-natural water bodies, this consideration underpins the desirability of maintaining a wide range of fish species and sizes, rather than managing the waters only for fish species of direct use to man.

4.3.7 Location of fish-holding facilities

Locating the most susceptible fish species or size classes close to centres of human activity or near buildings is a simple option for reducing cormorant impact at fish farm sites. For example, fish wintering basins and fishing gear in Italian extensive aquaculture facilities are often located close to buildings and areas most regularly used by humans. However, cormorants were not deterred from foraging here unless active deterrents (e.g. blank shots, shooting, human patrolling) were used as well, and the birds can also learn to feed intensively for short periods when humans are absent — during lunch breaks, for example.

Moving fish to less vulnerable sites may also be an option at some recreational fishery sites that feature a range of adjacent water bodies and where different species are kept in each.

4.3.8 Overview of fish stock management techniques

Efficacy

Where fish movements and stocking are carried out as routine fishery management practices, or within aquaculture operations, regulating these (e.g. timing and frequency of release, location or size of fish at release) can provide simple and effective measures for reducing cormorant predation. Such techniques are typically of short-term duration (weeks to months) and effectiveness will vary, depending on the flexibility in the timing of fisheries and/or aquaculture practices relative to periods of peak cormorant occupancy.

The use of alternative 'buffer' fish species is unlikely to be widely applicable (and artificially elevated fish stocks may attract more predators), but it may still be effective in certain instances — for example, where surplus fish are readily available during periods of peak cormorant abundance and can be stocked at waters away from sites sensitive to predation, or to relieve the pressure on key target species. Such measures may be best employed alongside other deterrents in order to maximise their benefits. The effectiveness of relocating the holding facilities for particularly sensitive fish is reported to be strongly dependent on the local situation. It has been reported to be ineffective in some situations, but effective over periods of days or perhaps months at others.

Practicality

Fish stock management techniques may be less widely applicable than other deterrents, and practicality is expected to range widely as a result of considerable site-specific differences. However, where regular stocking or fish movements take place anyway, this can provide practical options for reducing cormorant impacts at a range of fishery sites, including rivers, stillwaters and aquaculture facilities. Such measures might be incorporated into standard operating procedures where this is appropriate. In large water bodies and river catchments, fish stock manipulation may prove difficult or practically impossible to carry out.

It should be recognised that fish movements and releases into water bodies may be covered by regional and/or national regulations, and local guidance and any necessary approvals should be sought in advance.

Costs

The costs of implementing fish stock management techniques are likely to vary widely, dependent on the individual site, the flexibility available and the group of stakeholders concerned. However, in many instances costs can be low. Even where larger fish are stocked, the higher rearing costs can be offset by better survival, higher returns to anglers and greater angler satisfaction. This has been shown to provide a cost-effective option in some fishery situations, particularly for recreational trout angling in lakes. Similarly the cost of managing fish movements and rearing locations at aquaculture facilities can be low, particularly where these can be incorporated into standard operating procedures.

Acceptability

The use of fish stock management techniques is likely to be a possible solution only in certain sectors and will often be less widely applicable than other cormorant management techniques. Where applicable, it will have a high degree of acceptability in most instances. Anglers, for example, generally welcome the availability of larger fish and it is unlikely to attract criticism or comment from the general public. However, it is recognised that such an approach has limited use for many natural, sustainable freshwater fisheries where the stocking of atypically large fish to increase natural fish populations is generally not favoured on ecological and biodiversity grounds.

4.4 Reducing Fish Availability To Cormorants — Habitat Modification Techniques

The philosophy behind this set of tools is an extension of that described previously in relation to fish stock management. These tools aim to make sites less attractive to cormorants for either roosting or nesting, or as feeding sites. Such tools will never stop cormorants from roosting, breeding or feeding altogether. However, at a site-specific level they may reduce or eliminate cormorant presence in an area, prevent birds colonising, or may help to make foraging sites less attractive to birds, thus encouraging them to move

elsewhere. A possible danger is that this may result in greater dispersal of the cormorants in a region, leading to the establishment of new, smaller roost sites.

If there are no other safe roosting sites for some distance, cutting down a few trees on the banks of a pond may be enough to make a site unattractive for birds. Preventing the establishment of a cormorant roost site may stop cormorants being attracted to an area by the presence of other birds or may prevent subsequent attempts at breeding — roosts are often the precursors of colonies. As with most, if not all, of the techniques described here, their use will be most effective if applied with a good knowledge of the region and the behaviour, movements and daily foraging patterns of cormorants in the area. There are thus a number of options for reducing cormorant-fishery conflicts by altering the habitat both above the water and below it.

4.4.1 Elimination of resting or roosting places

It may be possible to cut down trees or modify the resting and roosting sites used by cormorants to make a nearby or adjacent foraging site less attractive. However, the long-term effectiveness and true cost of this approach is likely to vary with the function of the site, for example:

- Whether cormorants are using the site for breeding, potential breeding, night roosting or day loafing.
- Any adverse environmental or amenity impacts of tree removal.
- The availability of alternative local roosting and foraging sites.
- The effects of vegetation at the edge of water bodies on shade, temperature, and other aspects of microclimate and microhabitat.
- The impact of removal on tree populations locally and on other species that use the tree(s).

Thus, the removal of the only tree alongside a fishery or fish pond may prove effective for cormorant control, but could alter desirable shade, microhabitat and microclimate characteristics. This technique will generally not be appropriate for rivers or larger sites where there are numerous alternative roost sites available for the birds, as the removal of these resting places may prove impossible. However, the method can be targeted at a particular area, rather than at a single fish pond or fishery, particularly where feeding and roosting sites may be some distance apart.

The practicality and cost of removing or modifying roosts also depends on the type of structures being used as the roost site. For example, it may be possible to remove isolated trees or cover them with wires or netting, but commercially available anti-perch devices would need to be used for roosts on pylons or lamp posts. Other techniques such as pyrotechnics, bio-acoustics and laser light can also be used, either on their own or in conjunction with physical methods, to make roosts unattractive. On the Columbia River in the USA, researchers have had some success in relocating Double-crested Cormorant roost sites through the combined use of deterrents at existing roosts and the provision of alternative roost sites, complete with nesting materials/artificial nests elsewhere. This has been used to reduce the impact of cormorants on important migratory salmonid species.

Disturbing night roosts can be effective at deterring birds from a site. To prevent birds from using a night roost the cormorants should be disturbed repeatedly at the site at night using pyrotechnics or visual deterrents (described previously in this Toolbox). This should be repeated at least three times during the course of the night for a number of consecutive nights. By repeatedly arousing the cormorants and forcing them to fly around in the dark, the birds learn that the site is an unsafe place to spend the night and will find alternative sites.

This method is also highly effective at preventing birds from establishing new nesting sites, as they will initially roost in a site before building nests there. By demonstrating to birds that a site is unsafe they are less likely to begin nesting there. Once the nests have been built and the eggs are laid, it is very difficult to 'persuade' birds to leave using this method. In Israel, for example, a Pygmy Cormorant nesting site was successfully moved from an important fish farming area to a natural lake through repeated disturbance of night roosts prior to the nesting season. No birds were harmed and it was not necessary to destroy any nests.

'Disturbing night roosts can be effective at deterring birds from a site'

Cormorant roost in Israel. Photo courtesy of Bruno Broughton.

The destruction or disturbance of cormorant night roosts is used to deter cormorants in a number of countries around Europe. However, it should be remembered that, in some countries, nests (when in use or being built) may be protected under national legislation and it may be an offence to damage or destroy these without a licence.

4.4.2 Elimination of nests

Nest destruction is subject to formal controls in most countries and requires a licence. The technique is time-consuming, though relatively inexpensive if labour costs are ignored, and it can be very effective at controlling bird numbers in a specific area.

However, disturbance at colonies must be undertaken carefully in order to avoid the risk of spreading birds to new sites where they are not wanted. Nest destruction has been used at a site in America to reduce the impact of Double-crested Cormorants on local fish stocks and on the nesting habitats of other colonial waterbirds. Weekly visits to the colony were carried out, nests on the ground were removed by hand and those in trees dislodged with a telescopic pole; nesting material was scattered to discourage attempts to re-build the nests. This programme prevented further cormorant breeding in the area. In Denmark, the removal or destruction of nests is also used successfully to prevent the establishment of new colonies and to contain cormorant-fishery conflicts within certain areas. Descriptions of other methods for reducing reproductive success are provided in Section 4.5.1.

Other techniques can also be used to disturb birds and prevent nesting taking place. These include the use of audible deterrents, human disturbance and other visual deterrents (e.g. laser light, water jets and model helicopters and aircraft). Regular disturbance of adult birds at breeding sites can also allow predatory birds and carnivores to attack the nests and enhance the deterrent effect. In general, the use of other scaring methods together with nest disturbance and destruction is considered more likely to cause potential breeding birds to abandon an area. However, the possible disturbance of other non-target species must be taken into account when considering this technique, especially as cormorants often share their colonies with a number of other bird species. Further, if a site is part of the Natura 2000 network, deliberate disturbance would first require an impact assessment under the EU Habitats Directive.

4.4.3 Improving habitat quality for fish

Underwater habitat plays a key part in the interaction between fish predators and their prey. Weed cover and other submerged structures are widely used by prey fish to reduce the risk of predation from Pike (*Esox lucius*) and other fish predators. Research has shown that the survival of prey species can increase, and the growth of predators such as Pike decrease, as

vegetation density becomes greater. The extent to which similar factors might regulate interactions between cormorants and fish is less well established, but there is every reason to believe that they will apply to all fish-eating predators be they fish or birds. Indeed, prey accessibility as well as prey density has been shown to influence the foraging success of fish-eating birds and, consequently, the selection or abandonment of individual feeding sites. Thus, habitat features are expected to play a major role in the anti-predator behaviour of many freshwater fish species and in determining their vulnerability to predators.

Good habitat is vital for successful, all-round fisheries management and for healthy, sustainable fish stocks in both rivers and stillwaters. A successful fisheries management strategy might, therefore, be to provide sufficient cover for fish, recognising that the most cost-effective way of minimising the impact of predators on any fish population is likely to be by making sure that the environment provides fish with the best opportunities to use their natural defence instincts, as well as meeting feeding and spawning requirements. In seeking to provide adequate cover for fish in fisheries, there may be potential for enhancing natural habitat features through, for example, the creation of marginal reed fringes, permanent overhead and in-stream cover and off-channel areas (e.g. shallow pools, backwaters and ditches). Alternatively, the use of artificial refuge structures might be considered (see Section 4.4.4).

It is known that actions taken to improve habitat quality for fish are common and widespread across Europe, particularly in smaller rivers and stillwaters. Typically, these are implemented as general management measures to improve fish habitat and hence fish populations and are not undertaken primarily to reduce cormorant predation. However, reduced predation risk is quite likely to be an additional benefit of such improvements.

4.4.4 Artificial Fish Refuges

In some parts of Europe cormorant numbers are highest during the winter period when the natural cover available to fish is at its lowest because aquatic weed has died back. Fish swimming speeds, which are governed in part by water temperature, are also at their slowest during this period, and cormorants can swim faster than most of their prey species at this time of year. Using artificial refuges to modify the habitat and provide additional cover for fish could therefore be used to reduce their vulnerability to cormorants at a period of the year when they might otherwise be particularly at risk to predation. To be effective, such refuges need to both attract fish and provide them with protection from predators.

Investigations have shown that there are a number of key design features to help ensure fish use artificial refuges and confer some benefit. These are:

- Structure — many species of fish are attracted to natural habitat features, such as weed beds and underwater tree roots. The inclusion of some form of structure within a refuge is thus seen as an essential requirement to help attract and hold fish. Structure might be provided in a number of ways, for example: brushwood bundles, branches, old Christmas trees, frayed rope to mimic artificial weed, etc.
- Overhead cover — it is also well known that shading/overhead cover attracts fish. Additionally, shading also provides fish with an enhanced ability to detect oncoming predators. For example, a shaded observer can see a sunlit target at more than 2.5 times the distance that a sunlit observer can see a shaded target.
- Cormorant exclusion — Cormorants must be excluded from the refuge areas if these structures are to be effective. Refuges therefore need to be surrounded with a protective mesh to make them cormorant-proof. Research has indicated that use of a mesh of about 10 cm (e.g. typical stock fencing) will effectively exclude cormorants, while optimising access for fish.

Trials using simple cage refuges have demonstrated that fish will very rapidly locate and utilise these in the absence of other available cover. Fish prefer these structures to open water, particularly during daylight hours (when cormorant foraging occurs). Investigations at inland fisheries have also confirmed that large numbers of fish can locate and use refuges, although this appears to be moderated by the extent of existing available habitat (e.g. marginal reed beds) at any particular site.

Research in the UK has provided clear evidence that refuges can, in some cases, protect fish and

Simple cage refuge used in experimental trials in the UK. Photo courtesy of Ian Russell.

reduce the foraging efficiency of cormorants. A series of comparative trials were carried out in two identical, small (0.12 ha), shallow (1.35 m) rectangular ponds located in a disused water treatment works. The ponds were adjacent to one another and were drainable, such that fish stocks could be unambiguously sampled at the end of each trial. At the start of each trial, the ponds were filled and stocked with Roach and smaller numbers of Perch and Carp, with an overall stocking density between 259 and 459 kg/ha, consistent with those at many recreational stillwater fisheries in the UK. One of the ponds contained refuges and the other had none (control). The refuges were made from a number of individual cage units, each measuring 2 m x 2 m x 1.2 m high, and incorporated overhead shading (commercial shade netting), internal structure (small conifer trees) and an overlay of light-gauge stock fencing around all four sides and the top (see picture). Twelve refuge cage units were deployed in each trial, grouped in two discrete blocks of six. In total, the refuges represented about 3.5% of the water volume in the refuge pond. The upper surface of the refuge was approximately 15 cm below the water surface.

The results indicated that cormorant dive duration in the refuge pond was significantly higher and the foraging efficiency of the birds (prey capture rate and the proportion of successful foraging bouts) significantly lower. In effect, the birds were working harder for fewer captured prey. There were 77% fewer cormorant visits to the refuge pond than the control pond, on average. There was also a 67% fall in the mean mass of fish consumed per cormorant visit and 79% less fish mass lost in the refuge pond. The trials clearly demonstrated that, where alternative foraging sites are available, the presence of refuges can dramatically reduce the quantity of fish eaten by cormorants at a site and make a site less attractive to foraging birds.

While these large benefits were achieved with a refuge volume of 3.5% relative to the volume of the pond (no other cover was available), more recent trials have shown that smaller refuge volumes, down to between 0.5% and 1% of the pond volume, also have very marked positive effects. Indeed, while evidence derived from a range of trials using different sizes of refuge suggests that there is a positive relationship between refuge size and protection of fish — i.e. the larger the refuge size the better the protection provided — this is not a simple additive relationship. Thus, the largest net benefit, in the absence of other cover, results from the provision of even a small quantity of refuge.

The potential benefits of using refuges are likely to vary with the fish species present and from site to site. Initial evaluation suggests that refuges might be most suitable for smaller shoaling species such as Roach, Perch, Rudd (*Scardinius erythrophthalmus*), and small Bream and Carp, but a range of other species may benefit. Refuges may not be a suitable option in some recreational fisheries where it is necessary to have large 'snag-free' areas for playing larger fish, such as in specialist Carp fisheries. The size of a fishery and, possibly, the water transparency will also be important in deciding whether fish refuges are likely to be a practical option. Refuges are likely to be most effective in smaller stillwater fisheries (<5 ha), and costs and practicalities may preclude extending the technique to large water bodies, although in the absence of any cover even small refuge areas should provide some benefit for fish stocks.

The extent of existing natural cover at a site should also be considered in assessing whether refuges might be beneficial. Refuges may be of particular value in relatively featureless sites that have little or no existing cover for fish. Refuge placement is likely to be less critical in such sites, since investigations indicate that fish will quickly find and use the new structures. In such instances, trials have indicated that deploying refuges together in one or more bigger groups is likely to provide better protection for fish than using a large number of very small, widely dispersed refuges. However, where some existing cover is available, enhancing these natural features may be better than positioning refuges elsewhere. Thus, placing refuges adjacent to, and integral with, emergent vegetation may well be more beneficial than providing alternative refuge areas in open water, well away from any existing cover. Alternatively, protecting existing natural refuge areas, such as marginal emergent vegetation, through the use of fenced and covered enclosures, or adding additional natural features (e.g. tree branches), can represent effective alternative strategies.

Fishery managers have deployed fish refuges at a number of inland sites in the UK and a number of designs have been tried. The most widely used option to date has been that of small 'reefs,' constructed by joining together coils of stock fence. The coils of wire in such designs provide both the cormorant-proofing and some structure, although this can be further enhanced through the addition of brushwood or other materials; shade netting should also be included to provide overhead cover.

Refuges made from coils of stock fencing, UK.
Photos courtesy of Mark Ives and Martin Read.

Another popular option has been the use of floating refuges, sometimes referred to as 'eco-islands', since these can be planted with various emergent plants (rooted in coir matting). Once established, the roots from the emergent plants extend well down into the water providing cover for fish, and the vegetation also provides a habitat for other wildlife. Mesh enclosures should be suspended beneath the island to exclude cormorants and provide a secure refuge area for fish. This type of refuge has the advantages of being more 'natural' and aesthetically pleasing and is now commercially available in the UK. However, these designs are more expensive than some others.

There will, of course, be a number of constraints and practical limitations to using artificial refuges, and they may be impractical in large commercial fish-growing ponds with very high densities of fish. These structures may cause fish to aggregate unnaturally, a particular problem where competitive 'match' angling is practised. There is also the risk that, without appropriate identification, fishing tackle may become snagged, with the resulting loss of gear becoming a hazard for other wildlife. It will also be important to ensure that the refuge structures themselves do not pose a risk of entanglement for fish and other wildlife.

However, correctly designed to prevent birds entering them, refuges should provide the fish with some protection and help reduce expensive stock loss. Refuges could be used on a seasonal basis, being deployed only for the winter period, when fish are most vulnerable and there are usually fewer anglers fishing. Further details are available at: http://www.naturalengland.org.uk/conservation/wildlife-management-licensing/leaflets.htm#piscivorous.

Initial feedback from anglers in the UK and in other European countries has been largely positive, with perceived improvements in catches and fish abundance as a result of using refuges. Many anglers also reported that catches around fish refuges were good and that refuge structures were therefore often targeted as favoured angling 'marks'. However, to avoid problems with snagging gear and potential conflict with anglers it is recommended that the position of

Floating 'eco-island' refuges, UK. Photos courtesy of Mark Ives.

any refuges is clearly marked with small floats, and that they are sited to minimise impact on angling stations. It is also important that refuges are constructed carefully, using appropriate materials, to ensure that they do not pose any risk to fish or other wildlife.

While initial trials with refuges have mainly taken place in the UK, the technique is now also being trialled at stillwater fishery sites in a number of other European countries and in aquaculture facilities in Germany, Italy and Spain. Preliminary results are encouraging.

4.4.5 Overview of habitat modification techniques

Efficacy

Modifying the habitat, both above and below the water, can offer reliable, long-term (months to years) options for reducing cormorant predation. The removal of resting/roosting places has been employed at sites around Europe to deter cormorants from feeding in particular sites. The technique has been reported to be effective at some sites, with the proviso that much depends on the characteristics of the site, particularly its size and the number and proximity of alternative roost and foraging sites, as well as the ecological and other costs associated with roost removal.

While not specifically targeted at managing cormorant-fishery conflicts, the effective management of water bodies to optimise environmental conditions for fish will go a long way to ensuring that fish populations are maintained at healthy and sustainable levels.

Targeted management of the natural environment, or the use of natural or artificial structures, can also be used to provide additional cover for fish and reduce cormorant impact. Trials with artificial fish refuges have demonstrated that, where alternative foraging sites are available, the presence of refuges can dramatically reduce the quantity of fish eaten by cormorants at a site and reduce the numbers of cormorants visiting that site.

The size of a water body, the extent of existing natural cover at a site and the fish species present are all likely to affect the efficacy of artificial fish refuges. These may be of particular value in relatively featureless sites that have little or no existing cover for fish and that contain smaller shoaling species.

Practicality

The applicability of habitat modification techniques will inevitably be constrained by practical considerations. The removal of cormorant resting or roosting sites is probably only practical at smaller sites, or in localised areas, where birds have limited alternative roosting options; the use of additional deterrent measures may help with making such sites less attractive. Similarly, the size of a fishery will be important in deciding whether or not fish refuges will be a practical option. Refuges are likely to be most effective in smaller stillwater fisheries, and costs and practicalities may preclude extending the technique to larger stillwaters and rivers. The deployment of refuges must take account of the needs of recreational fishermen and any other water users and ensure that they do not represent a hazard to other wildlife. There is also potential to utilise refuges on a seasonal basis, deploying them only for the winter period when fish are most vulnerable (and fishing effort typically at its lowest).

Costs

The costs of habitat management techniques will vary considerably depending on their scale. For example, the cost of removing a single roost tree at a site would be low, while more extensive roost management measures over a larger area, or at a number of sites as part of a broader scale plan, would be relatively high. Costs may also be affected by any overarching objectives. Thus, incidental benefits (at minimal costs) might be expected from general habitat improvement works, with higher costs likely for actions targeted specifically at cormorant-fishery interactions. Fish refuges also vary markedly in price depending on the numbers used, their design, the materials used and the manpower costs. Costs can be substantially reduced where labour can be provided on a voluntary basis — by stakeholder groups, for example. However, for all habitat management techniques, the cost-effectiveness should take into account the potential durability and long-term efficacy of the measures, as well as the scale of the losses to predators. It should be viewed against the potential recurrent costs of using alternative deterrent measures.

Acceptability

Habitat modification techniques are generally considered to have a high level of acceptability. Widespread removal of roost trees might attract

criticism from the general public and raise aesthetic concerns, but such actions on a broad scale are unlikely to be realistic or cost-effective anyway. General habitat improvement initiatives are usually highly acceptable and broadly welcomed. In relation to artificial fish refuges, feedback from anglers has been largely positive, with perceived improvements in fish abundance at sites containing refuges. Many anglers have also reported good catches around fish refuges, with the structures often being targeted as favoured angling 'marks'. To avoid potential problems with the snagging of fishing gear it is recommended that the position of any refuges is clearly marked with small floats, and that they are sited carefully. It is also important that refuges are constructed correctly so that they do not pose a hazard to birds, fish or other wildlife.

4.5 Killing Cormorants- Lethal Measures

It is not surprising that the notion of killing cormorants is very attractive to many stakeholders. After all, a dead cormorant represents one less bird to eat fish. Killing cormorants also gives the satisfaction of an 'instant solution'. However, it must be remembered that cormorants, like most wild birds, are subject to legal protection throughout much of their range. In Europe, cormorants are protected under the Birds Directive. Article 1 of the Directive provides that all birds naturally occurring in the wild and their habitat should be protected; this extends to their eggs and nests as well as all stages of their life cycle. Article 5 of the Directive requires Member States to prohibit the deliberate killing of all naturally occurring wild birds, unless this is carried out under the provisions of Article 7 or 9. Article 7 allows the hunting of certain species listed on Annex II of the Directive; this does not include the cormorant. However, Article 9 provides that Member States may derogate from the protection of the Directive for a number of purposes, including preventing serious damage to crops, livestock, forests, fisheries and water, or the protection of flora and fauna, provided that there is no other satisfactory solution. Current information on lethal measures taken across Europe is summarised in another **INTERCAFE** report (see 'Cormorants and the European Environment: exploring cormorant status and distribution on a continental scale'[1]). The numbers of birds killed or taken under such derogations have to be reported to the Commission annually.

However, there are problems with killing birds in practice because dead birds are very often quickly replaced by others. This is particularly true at sites on cormorant migration routes especially in autumn and winter. It may also be the case at other times of year if cormorants are moving freely between locations. Shooting cormorants is usually done for one of three reasons:

1. As an aid to scaring, in order to reinforce other deterrents (often auditory or visual ones).
2. To (temporarily) reduce the number of individual birds feeding at a particular site.
3. As a larger 'cull' with the intention of reducing cormorant numbers over a wider area or at the population level.

Increasing numbers of cormorants need to be shot under these three scenarios.

Cormorants can also be killed at other stages in their annual cycle and perhaps the easiest is to take advantage of cormorants' colony formation and to destroy nests or eggs at breeding sites. In theory at least, such nest or egg destruction will reduce the breeding output of the birds (see below) — so that, ultimately there should be fewer fledged birds at the end of the breeding season, fewer older birds to visit fisheries in winter, and, subsequently, fewer adult birds to breed. However, like most animals, cormorants are both flexible in their breeding behaviour and their populations are quite resilient to mortality — particularly if experienced early in the life-cycle. For example, it is possible for cormorants to re-build their nests (sometimes at new sites) and to re-lay clutches of eggs. A reduction in breeding birds in an area also often leads to an increase in the numbers of young birds per nest that are fledged successfully. This is thought to be a consequence of the reduced competition among cormorants for food and the greater availability of fish with which adults can feed their offspring. Similarly, reducing the breeding output of one, or a few, colonies may relax feeding pressure on some sites, allowing other birds to capitalise and improve their own breeding output.

Such 'density-dependent' relationships are common in nature, making it particularly difficult

[1] van Eerden *et al.*, (2012) COST Action 635 Final report I.

to reduce numbers over large areas or at the 'population' level. Indeed, it is likely that the greater the (downwards) 'pressure' that is applied to reduce bird numbers, the stronger will be the (upwards) compensatory mechanisms that will operate to re-build population sizes. For cormorants, such density-dependent factors operate both within and outside the breeding season.

Typically, lethal measures are applied at a relatively local, often site-specific level, where effects are likely to be relatively short term in nature. The aim is to reduce the numbers of cormorants visiting specific sites or areas.

However, the use of lethal measures (in combination with other non-lethal deterrents) can also be coordinated over a wider area — for example, to protect a network of particular habitat types, or to deter birds from using areas containing valuable, extensive aquaculture facilities. Examples of such coordinated approaches are provided in the Case Studies section at the end of this Toolbox.

This sort of coordinated approach, if applied consistently, also provides a way of avoiding, at least in part, the problem of constantly fighting density-dependent, compensatory mechanisms. If birds can be restricted to a particular area and their expansion to other surrounding ('no go') areas is controlled, the population within the restricted ('permitted') area would become regulated by the available resources (e.g. food and breeding sites). In such a scenario, numbers would be expected to oscillate about some equilibrium or carrying capacity level, regulated by density-dependent factors. Active measures would be required outside this area in order to restrict expansion and, of course, this would not be easy, particularly at a larger scale. Nonetheless, such an approach may have applications in certain situations.

There have also been continued calls from some stakeholder groups for longer-term, internationally coordinated cormorant control at the pan-European level, with the aim of reducing the overall population size of cormorants across Europe. The possibility of control at this level has been the subject of previous investigation using population models, with efforts to determine the levels of control necessary to reduce the overall population size and to predict the ultimate size and distribution of the population. The widespread nature of cormorant breeding populations, with birds mixing and dispersing across Europe in winter, makes this a particularly challenging task. Nonetheless, efforts have been made here to summarise the main outcomes of this work and the factors likely to influence or constrain such a widespread management approach.

'Egg destruction is used in several countries to reduce local populations of Cormorants'

Cormorants shot on an Israeli fish farm.
Photo courtesy of Ian Russell.

4.5.1 Reducing Reproductive Success

The technique of egg destruction is used in several countries to reduce

local populations of cormorants (see Section 4.4.2). As with other lethal methods, this may be subject to formal controls and require a licence. This technique is generally only useful for ground-nesting cormorants as it is more difficult and costly to reach nests in trees. Eggs can be destroyed by several methods: egg removal, egg pricking or egg oiling, although oiling is the method most commonly used and generally regarded as a cheaper, more effective and more humane method of egg control. This technique involves coating the egg shells with oil such as liquid paraffin or vegetable oil, which stops air from passing through the shell to the embryo, thereby preventing it from developing properly.

A number of factors can influence the efficacy of different egg destruction methods. For example, egg removal can encourage re-laying unless eggs are replaced by hard-boiled or wooden replicas, some pricked eggs may still hatch, and birds may abandon treated clutches to re-lay eggs elsewhere. The efficacy of egg destruction is also believed to vary among species.

The oiling of eggs is widely used on Double-crested Cormorants in the USA and Canada to reduce cormorant hatching success and to prevent colony establishment. It has the advantage over egg-removal or destruction in that the adults will not lay a new clutch and will continue to sit on the oiled eggs until it is too late in the season to breed effectively. Studies in North America have shown that there may be an increase in dispersion of cormorants from nesting colonies where oiling takes place, but this can be prevented if a small number of chicks are present in the colony. To be effective, oiling needs to be repeated approximately every two weeks to ensure almost all the eggs are oiled. Studies have shown that in order to be successful in the long run, at least 74% of the eggs need to be oiled, and one cannot expect to see reduction of the population for at least two years, since cormorants do not reach sexual maturity until two years old.

Oiling has been used in a number of colonies around the eastern basin of Lake Ontario in recent years. This has been carried out using a backpack sprayer on five occasions during the incubation period, at two to three week intervals, to ensure

Egg oiling, Denmark. Photos courtesy of Henrik Lykke Sørensen.

that each readily accessible nest was treated at least twice over the period. A simple model has been developed to estimate cormorant feeding days and fish consumption in treated colonies relative to other local untreated colonies. Thus, egg oiling at one island colony in 1999 was estimated to have reduced the number of cormorant chicks produced by 8,300, while fish consumption over the breeding and rearing period was estimated to have been reduced by around 28% (~350 t).

Because of seasonal variation in the diet of cormorants in the area, this oiling work is thought to provide the greatest protection for those fish species that feature most prominently in the diet during the chick-feeding and post-chick feeding periods (assessed from pellet analysis). This includes the commercially important Smallmouth Bass (*Micropterus dolomieu*).

In Europe, the technique is in common use on Great Cormorants mainly in Denmark where it has been used mainly in the large, ground-nesting colonies in western and northern Jutland to reduce the number of cormorants foraging in the fjords in West Jutland. The following examples illustrate that the effects on cormorant numbers in subsequent years can vary depending on local conditions and conditions elsewhere.

Example 1 — Egg oiling followed by an expected decline

In the Rønland Sandø colony in northwest Denmark, 80–93% of all nests were exposed to egg oiling from 2003 to 2008. It was expected that breeding numbers would begin to decline at a rate of about 10% per year from 2006 onwards. Contrary to expectations, breeding numbers increased in 2006 (Figure 2), probably due to immigration from the nearest neighbouring colony where nest numbers declined by 350 nests in 2006. However, as predicted, breeding numbers declined in 2007 and 2008. The marked decline in 2008 might be a result of a combined effect of lack of recruits due to the egg oiling and poor food conditions in that year leading to non-breeding among some potential breeders.

Example 2 — Egg oiling followed by a decline then an increase

In the colonies in Ringkøbing Fjord in West Jutland, 80–93% of all nests were exposed to egg oiling from 2003 to 2008. As anticipated, nest numbers began to decline in 2005–2006, but contrary to expectations, breeding numbers increased markedly in 2007 and 2008 (Figure 3). Some of the increase in 2007 was explained by re-nesting of the same birds in a new colony established late in the season. However, re-nesting could not explain the increase in 2008. Records of ringed birds among breeders showed that the increase in 2008 was partly or entirely due to immigration. The sudden immigration was probably related to a marked increase in the local abundance of Flounder (*Platichthys flesus*) which provided prey of the right size for cormorants. The ringed immigrants were a combination of young birds that presumably bred for the first time and older experienced birds that had nested in other colonies. Most of the ringed immigrants came from colonies located within 170 km from Ringkøbing Fjord, but there were also cormorants raised 300–700 km away.

The process of egg oiling (or other egg destruction methods) is time-consuming and labour-intensive, since as many nests as possible may have to be located and treated, and this can be hindered by problems of access (particularly

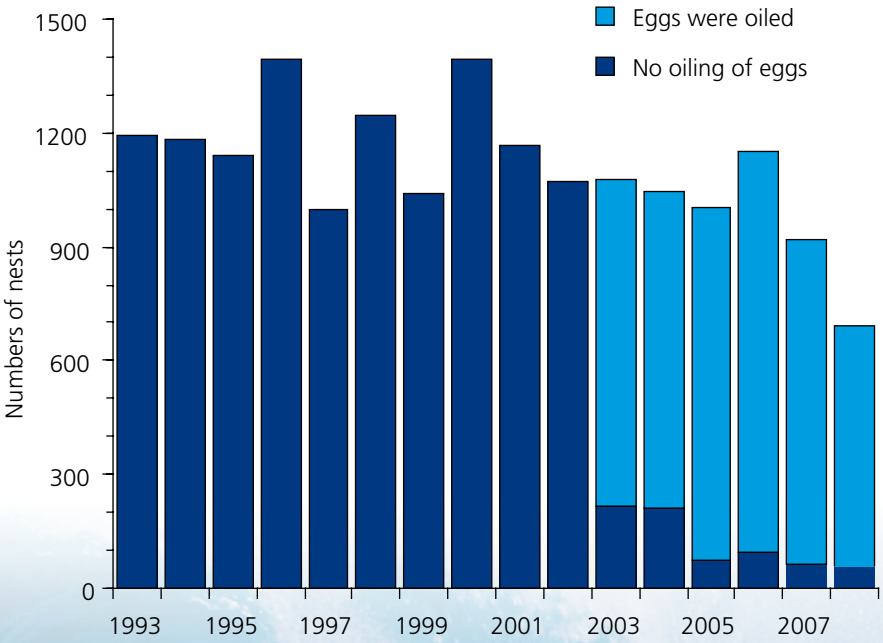


Figure 2 Cormorant nest numbers in the Rønland Sandø colony in northwest Denmark 1993–2008. The lighter shading in the columns indicates nests exposed to egg oiling.

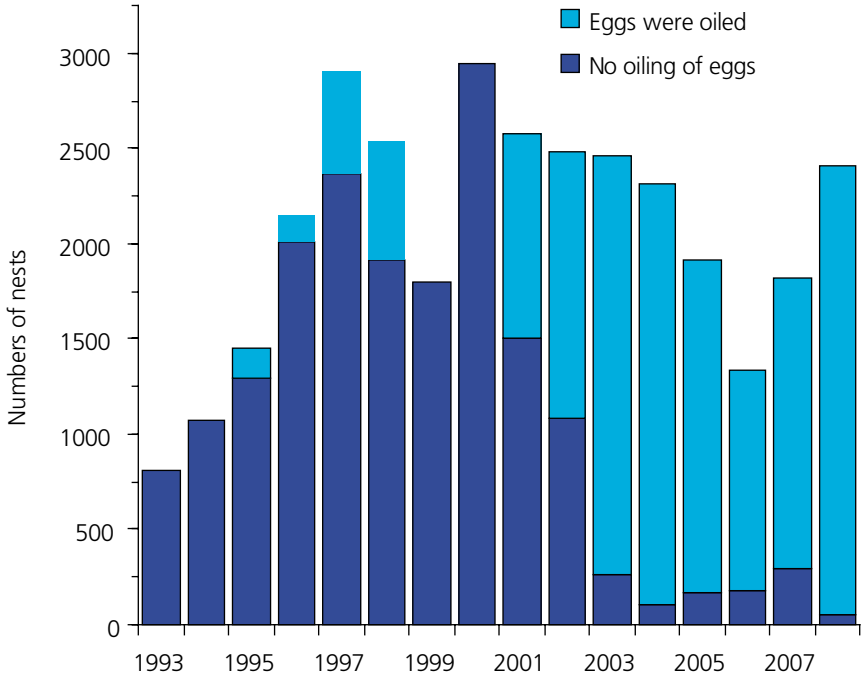


Figure 3 Cormorant nest numbers in Ringkøbing Fjord in West Denmark 1993–2008. The lighter shading in the columns indicates nests exposed to egg oiling.

for tree-nesting cormorants). For total success, spraying may also need to be undertaken several times during incubation and this increases costs. The timing of destruction is also important in order to minimise the risk of birds re-laying. It should also be recognised that any reduction in a population caused by the loss of young birds can be offset by immigration of new birds from nearby non-treated areas, particularly if the technique is employed as a short-term measure.

Intense harassment of adult cormorants at nesting colonies has been used to reduce reproductive success by allowing predatory birds and carnivores access to the nests. If the harassment is intense enough, the adults have even abandoned the nests all together. The most effective harassment is human presence but scaring techniques (as described previously) can also be effective, especially if employed at night.

4.5.2 Shooting — at a site-specific or local level

Shooting is one of the most commonly used techniques for reducing cormorant numbers at various sites, and killing cormorants by shooting is permitted in most, but not all, European countries in appropriate circumstances. Indeed, in a small number of countries cormorants are on the list of 'huntable' birds. For instance, in Norway there is a tradition of hunting the birds for food. The majority of birds that are killed in Europe are shot at feeding sites outside the breeding season, or in the vicinity of fishing gear, but in some countries breeding birds are also shot. Country, regional or site-specific limits may be placed on the numbers of birds that can be shot and shooting may be confined to specific regions or waters, or may be restricted in other ways (e.g. only near fish farms or fishing gear, or using only non-toxic ammunition). Thus, anyone wishing to shoot cormorants should be aware of, and comply with, any regulations and controls that apply in their country/area.

It has been demonstrated that both shooting to scare and shooting to kill a small number of birds as an aid to scaring can reduce the number of birds at a site for the duration of the shooting period and for a 'post-treatment' period. In the UK, a large-scale experiment was undertaken involving thirteen six-week field trials carried out over two years at a range of fishery types (including river and stillwater fisheries, stocked and unstocked sites, and fisheries with and without cormorant night roosts). The experimental design involved three treatments: control (no shooting), lethal shooting and non-lethal shooting (at the same intensity). Each six week trial was divided into three two-week phases: pre-treatment, treatment (when shooting was carried out) and post-treatment. Numbers of cormorants were then compared before and after commencement of shooting and between control and shooting sites.

The results indicated that shooting (to kill or to scare) significantly reduced the number of cormorants for both the treatment and post-treatment phase. An average bird reduction of over 50% was reported. However, bird numbers recovered to pre-treatment levels over a period of two to six weeks. Thus, to be effective in the longer term, such shooting would need to be repeated at regular intervals. Localised shooting has also been shown to be effective on the Sava Bohinjka River, Slovenia, where wintering birds (around 200) were removed from an area after

two winters of relatively intensive shooting (see Case Study No. 4).

An investigation to assess whether shooting in the autumn/winter (the hunting season) would be an effective means of reducing cormorant numbers at large water bodies, and perhaps advance the autumn migration of the birds, was recently carried out in Denmark. A three-year experiment was conducted in two fjords in West Jutland, with more than 190 hunters in each fjord issued with a licence to shoot cormorants from 1 September to 31 January (the hunting season). However, in each season only 22–59 hunters actually shot at least one cormorant. A total of 1,131 cormorants were shot in the two fjords over the three hunting seasons. These birds were estimated to constitute 3–7% of the cormorants that occurred in the fjords during the September to January period.

In Nissum Fjord, cormorant numbers declined immediately after the onset of one of the three hunting seasons to around 25% of the numbers present in the weeks prior to 1 September (Figure 4). Numbers did not increase again later in autumn, probably because shooting continued during September and because the number of new naïve birds arriving after mid-September was modest. The clear impact on autumn staging numbers was probably the result of intensive shooting over a few days near to the main night roost and close to some of the day roosts. In the other fjord, Ringkøbing Fjord, no marked decline in cormorant numbers occurred after the onset of shooting and up to 2,000 cormorants were present on the day roosts until mid-October. Shooting in Ringkøbing Fjord was uncoordinated and dispersed over most of the feeding area. Furthermore, all forms of human activities were prohibited within 1,000 m of the islet used by cormorants as their main day and night roost.

It was concluded that it may be possible to use shooting as a tool to make cormorants leave larger water bodies earlier in autumn (at least in northern Europe). However, success may require coordinated shooting near to day and night roosts.

It is generally accepted that killing cormorants enhances the scaring effect of shooting. However, scientific evidence to substantiate this view is not clear, and both shooting to kill and shooting to scare have been shown to be effective at reducing bird numbers at specific sites. The effectiveness of shooting depends on a number of factors: the target species, the site characteristics and the shooting regime. Individual birds of the same species may also respond differently. For cormorants, shooting is more effective at smaller sites than at large ones. The number of shooting parties/events and the number of consecutive days over which shooting occurs have also been shown to affect the magnitude of reduction in bird numbers. It is generally accepted that shooting is best used in conjunction with, and to reinforce, other non-lethal deterrent measures. However, in order to be effective over a wider area, shooting, and the use of any other associated deterrents, also needs to be coordinated effectively - for example, see Case Study 7 — Hula Valley.

The weapons and ammunition used for killing cormorants may also be stipulated under national or regional regulations, and individuals will probably also require firearms certificates or licences to cover their use (as well as the permission of land owners). The most commonly used weapon is a 12-bore shotgun. The loud

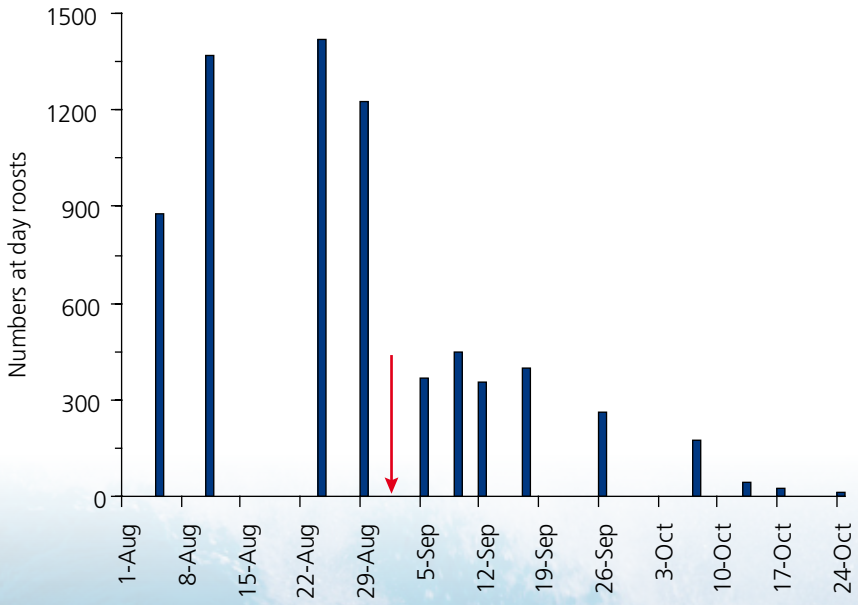


Figure 4 Numbers of cormorants present on day roosts in Nissum Fjord in West Jutland in 2003. Shooting of cormorants took place from 1 September (indicated by arrow).

report made by such weapons, and the need for the shooter to be in reasonably close proximity to the birds, maximise the scaring effect. Targeting individual birds within a group of cormorants, so that surviving birds are conditioned to avoid the site in future, will also enhance this. However, rifles may also be permissible in some situations. These have longer range than shotguns and may be particularly useful for removing lone birds or specific, persistent individuals; they will also generally cause less disturbance to other water birds.

The use of rifles is likely to have limited, if any, effect in conditioning other birds, so there may well be little potential scaring effect of killing birds with rifles. Safety will be a key consideration with regard to any use of firearms, but it will be a particular concern where rifles might be used. Bullets can travel for distances of over 2 km and may ricochet off water, rocky outcrops, gravel banks and other surfaces. Thus, rifles will not always be suitable for use on or near water bodies, particularly where there is public access.

4.5.3 Shooting — coordinated culling for population control

The use of lethal techniques for population control at a broad scale is constrained by a range of factors, including the level of mortality achieved relative to immigration and breeding rates, migratory patterns and the relative levels of controls in different areas. For a number of bird pest species, shooting has proved largely unsuccessful at reducing overall numbers. This may reflect the fact that the numbers killed by shooting did not exceed the recruitment rate from immigration and breeding. Thus, shot birds were quickly replaced by individuals from elsewhere. Alternatively, shooting might have mainly killed 'surplus' birds that would otherwise have died of natural causes such as starvation or disease. Commonly, population control has proved most cost-effective and long-lasting where the bird species causing problems have been relatively small, localised populations. Examples of the use of relatively large scale cormorant population control measures in France, the Czech Republic and Bavaria (Germany) are provided in the Case Studies section (Section 6).

There have been a number of efforts to model cormorant population growth in Europe in a management context and to investigate the interplay between large-scale cormorant culling and aspects of the species population dynamics. A simple model scenario, based on the 1998–9 continental cormorant populations (then estimated at around 100,000 breeding pairs), suggested that the then current level of culling (around 17,000 birds per year) would have limited effect. It was predicted that this degree of culling would result in a stable suppression of population size of less than 10% below the equilibrium population expected in the absence of culling. The models suggested annual culls of over 30,000 birds across Europe would still have only a limited effect, whereas shooting 50,000 birds would result in long-term population declines in Northern Europe.

This model also suggested that increasing the number of culled cormorants was risky, since once the compensatory power of the population is overcome, it will inevitably decline towards extinction if the cull is unchecked. One general inference of the model was that culls would need to be planned so that they became the most powerful, density-dependent mechanism affecting the target population. It was felt that this would require a well-parameterised population model and would also need to be accompanied by monitoring programmes and appropriate feedback mechanisms.

One drawback of this early model was that it did not take into account geographical variation in culling intensity. Managers, however, will often be most interested in the local effect of culls, which will depend on both local culling intensity and the extent to which the local population is isolated from other cormorant populations. This will depend on how 'attached' cormorants are to particular areas and on how much movement there is between locations, particularly in winter. Thus, local culls will have a greater effect on 'closed' populations, with little, if any, interchange of birds, than it will on 'open' populations where there is a lot of bird movement. Taken to extremes, for a place where birds are absolutely site-faithful (i.e. they go there and only there), a cormorant population could be controlled without any measures being necessary elsewhere. However, if birds distribute themselves randomly across the continent, the effects of culling at particular sites will only be manifest at the scale of the

overall wintering range and not at specific sites per se.

A later model was developed that included some geographical sub-division of the winter range (France vs. the rest of Europe), as culling intensity has been higher in France in recent years than elsewhere in Europe (see Case Studies). The model confirmed that the effects of culling are highly dependent on the extent of immigration into an area, and it suggested that culls at the present level in France could only be sustained as long as substantial immigration occurs. It was suggested that even a relatively minor increase in the present cull could lead to a crash in the French cormorant population. However, the effects of the annual culls outside France were predicted to be very small (about 3% on average), although they could be higher than this locally.

Such modelling work has indicated that cormorant population control through culling is feasible, in principle. In practice, there are many biological reasons why attempts to reduce the continental cormorant population would be extremely difficult. However, there is also a widespread view that population-reduction culling may not be the most efficient, practical, economical or ethical way of limiting cormorant damage to fisheries, and other interests, across Europe.

The use of population modelling as a tool to predict the consequences of culling has also been tested during a recent EU-funded project on fish-eating mammals and birds in conflict with humans (FRAP — Framework for biodiversity Reconciliation Action Plans — see: http://www.frap-project.ufz.de/). A generic matrix model was developed and specific modelling was carried out for cormorants and other species. The modelling of cormorant populations was based on published and unpublished information about the demography of cormorants breeding in Denmark.

To make this generic matrix model potentially usable for practitioners (especially managers and decision-makers), a special tool was developed: the so-called FRAP-Calculator. This software uses the demographic attributes of the species as input and allows appropriate population management scenarios to be tested. This model describes the development of the population over time and provides outputs which include: the number of individuals in different age classes, the number of breeding and non-breeding birds, as well as the risk of extinction of the population after 100 years.

The model allows different types of population management to be assessed and compared, such as culling of adults, eggs or manipulating the breeding capacity (e.g. by keeping birds from exploiting certain areas). For example, the modelled effect of various intensities of egg oiling on the development of pre-breeding numbers of cormorants in the cormorant population in Ringkøbing Fjord, Denmark predicts that this population will go extinct within 100 years if all the eggs in more than 85% of the nests are oiled annually. It also indicates that there is a critical level of 75% of nests, above which the population collapses sooner or later. This provides an example of how modelling can be used to identify threshold values for certain key parameters related to population viability, above which regulation management can be continued, but below which it has to be stopped in order to avoid jeopardizing the viability of the managed population.

The modelling also demonstrated that constant population management with fixed rules, quotas or rates was either too ineffective in terms of population reduction or too risky for population viability. Hence, an adaptive management approach was suggested, which with increased levels of monitoring would allow management rules to be adopted taking the current state of the population into account. This was judged to be both effective and safe, since it provided feedback mechanisms and the opportunity to stop control measures before the population was critically reduced.

Modelling and an adaptive management approach have previously been used in England to determine a prudent upper limit of cormorant numbers allowed to be shot each year. A policy change, in 2004, allowed the number of birds shot under licence to be increased from around 500 per annum up to a maximum of 2,000 per annum, although with the potential to increase this to 3,000 per annum in the first two years. The policy was supported by a stochastic Monte Carlo annual population model, which was produced to examine the effect of changes to the numbers of birds shot each year.

An index of the annual cormorant population size in England (the

annual WeBS-wetland bird survey — count) was converted to a population estimate based on the latest available data and was used to determine annual population growth rates, and the presence and strength of density dependence. The model was used to produce short-term population projections based on different levels of shooting. For example, it was estimated that the 1,300 birds shot under licence in 2004/05 represented about 4.5% of the English population, and that if this level of shooting continued the population would be expected to decline by 3% by 2007, compared to the long-term average, and increase the risk of decline by 4%.

Enhanced monitoring and Adaptive Resource Management (ARM) are now applied to allow continuous evaluation of the effects of culling on development of the population. Thus, the model parameters and model are updated, and this allows the number of birds licensed to be shot each year to be reviewed and, as necessary, adjusted should the population respond in a manner other than that expected.

4.5.4 Recent information on lethal actions against cormorants in Europe

In 2003, information summarising the extent of lethal measures applied against cormorants was compiled for each of the 25 countries involved in the EU-funded REDCAFE Framework 5 Concerted Action[2]. During the **INTERCAFE** Action, this information was updated and data for 30 countries are summarised in Table 1. It should be noted that the compiled information has been derived from both published sources and informed estimates from the various experts involved in the Action. These estimates should not be regarded as an authoritative, official, or even a particularly accurate estimate. However, it is felt that **INTERCAFE's** most recent data (mainly relating to information for the year 2006 or the winter 2006/07) do provide a reasonable basis for comparison with the REDCAFE data (compiled in a similar way) and a means for indicating possible trends.

The information in Table 1 is summarised merely to offer the reader some sense of the scale of lethal activities undertaken against cormorants across Europe under current legislation. The data are comprehensively described and discussed in the **INTERCAFE** publication 'Cormorants and the European Environment: exploring cormorant status and distribution on a continental scale'.

4.5.5 Overview of lethal measures

Efficacy

Egg destruction methods are time-consuming and labour-intensive, and they can be hindered by problems of access and may need to be repeated several times during the course of incubation to be effective. The loss of young birds can be offset by immigration of new birds from nearby, non-treated areas, particularly if the technique is employed as a short-term measure.

[2] Carss, D N. (ed.) (2003): Reducing the conflict between cormorants and fisheries on a pan-European scale: REDCAFE. Final Report to European Union DG Fish, August 2003, pp169. Available to download as REDCAFE Final Report at http://www.intercafeproject.net

Table 1 Summary of lethal measures against cormorants in Europe, comparing 2001/02 with 2006/07 (* denotes estimates are minimum values).

Lethal Measure	REDCAFE 2001/02	INTERCAFE 2006/07	Main countries where measures used
Breeding colonies destroyed/ disturbed	50	63*	Sweden, Denmark
Nests destroyed/eggs oiled	7,094–8,094*	9,845–10,845	Denmark, Sweden
Nestlings killed	600–700*	0	Germany
Adults killed (non-breeding season)	51,953–54,003*	86,520–89,680*	France, Germany, Norway
Breeding adults killed	3,598*	4,175–4,180*	Sweden, Italy
Night roosts destroyed	248*	510*	France, others

However, research has demonstrated that intensive egg destruction can reduce the size of breeding colonies in an area in the long-term.

Shooting cormorants to reinforce other, non-lethal harassment and to reduce bird numbers at local sites is widely used across Europe. Its effectiveness is generally short-term, ranging from days at larger sites to weeks or months at aquaculture facilities and smaller fishery sites. Typically, shooting is only effective over a longer period where the measures are targeted at stable bird populations with little exchange ('turnover') of birds.

The success of shooting depends to a large extent on the nature of the local cormorant population. However, efficacy also depends on factors such as the physical characteristics of the site, the shooting strategy and the availability of alternative sites to which the birds can move. Shooting may thus just move birds to alternative feeding sites in a locality and alter their distribution, rather than reduce their overall numbers in an area. Shooting is thought to be most effective where it is used in combination with other deterrent measures.

Field studies at sites in Europe (e.g. Germany, Austria and France), where shooting has been carried out on cormorants migrating between breeding and winter feeding areas, have indicated that shooting was not generally effective in reducing cormorant numbers, with shot birds being rapidly replaced by birds from elsewhere, especially at attractive feeding sites. This is in contradiction to theoretical simulation models and probably reflects the fact that rapid movements of birds have been underestimated by such models which are based mainly on ringing data from adult birds. Young birds are probably more erratic and less predictable in their movements.

The efficacy of large-scale population control will be constrained by many factors. For example, the large territory occupied by the birds, with widespread breeding populations and birds further mixing and dispersing in the winter, means that there will be no simple relationship between management actions in breeding areas (e.g. in one country) and the consequences of these actions for wintering areas, or vice versa. Further, since numbers and distribution patterns of the birds are partly determined by density-dependent factors operating both within and outside the breeding season, the population as a whole has considerable potential to compensate for reductions in numbers.

If successful, any reduction and stabilisation of the cormorant population at a lower level as a result of culling would reduce the overall impact of the birds on fish stocks and fisheries. At its simplest, if there were fewer cormorants across Europe they would eat fewer fish. However, it is highly unlikely that this would result in an even decline in the pressure on perhaps all but the poorest fisheries, as birds are likely to continue to favour high quality habitats that offer the best foraging potential. Where cormorant populations are constrained by available resources, studies have demonstrated that a reduction in bird numbers results in the abandonment of marginal, sub optimal, foraging areas first. Thus, although generally fewer birds should mean fewer fisheries with problems, the problems are likely to persist at many sites, particularly the 'best' ones (e.g. fish farms), unless a major reduction in cormorant numbers is achieved.

Practicality

The practicality of egg oiling (or other egg destruction methods) depends to a large extent on the accessibility of cormorant colonies and individual nests. Clearly, the technique is much more practical for localised ground-nesting colonies than for tree or cliff-nesting cormorants. For lethal shooting, practicability ranges from low to very high depending on factors such as the size of the water body to be protected, manpower availability and the nature of the local cormorant population (e.g. relatively sedentary or highly migratory). Shooting may also be constrained in some areas due to the proximity of human habitation, designated nature conservation sites or in areas of public access due to safety concerns.

Where lethal measures are to be employed on a larger scale — for example, to protect particular areas — an additional significant practical consideration will be the need to coordinate actions effectively. This may require the establishment of collaborative stakeholder groups and effective, real-time communication networks to ensure that efforts are targeted to best effect at appropriate times and places — see Case Study 7, Hula Valley. Thus, knowledge of the local behaviour, movements, and favoured locations (for foraging, roosting, loafing and feeding) of the cormorants will also be needed.

Costs

The application of all lethal techniques requires repetitive use of manpower, so costs depend to a large extent on whether or not wages are paid to those involved in any control programmes; costs can be substantially reduced where manpower is available on a voluntary basis, or where it may be possible to implement controls in conjunction with other activities (e.g. hunting, or as part of normal fish husbandry activities). Where dedicated wages are paid, costs will be relatively high, and the costs of weapons and ammunition can also be substantial. Beyond this, the costs will mainly be dependent on the scale of the programme, ranging from relatively modest costs where such techniques are employed locally and in the short term, to very high costs where such techniques are used over a broad geographical scale and on a recurrent basis.

Acceptability

The acceptability of lethal control measures varies considerably, and depends to a large extent on the viewpoint of the stakeholders involved. For a fishery owner or fish farmer faced with a cormorant problem, shooting to kill may be seen as a particularly acceptable option. For these it can readily be regarded as taking positive action towards solving a bird problem ('one dead cormorant is one less that will feed on fish'), and provides some immediate sense of satisfaction for the shooter. The use of lethal control measures to address localised or short-term conflict issues is commonly seen as a necessary and acceptable management option, with general support from many stakeholder groups.

However, large-scale population control at a national or pan-European scale is much more contentious, and while this is advocated by some stakeholders it is contested by others. There are particular concerns that should unregulated control be permitted, this could lead to sustained decline and possibly local extinction of cormorants. A coordinated, and appropriately regulated, pan-European population control plan might allay such concerns. However, there is also awareness that the killing of any wildlife can attract comment and criticism from the general public and that killing on a large scale may not be publicly acceptable. Some governments are therefore unlikely to find such an approach acceptable.

In common with shooting to scare and other audible deterrents, the noise of lethal shooting can have negative impacts on other wildlife and people. The acceptability of lethal measures may also be affected by the presence of bird carcases and concerns about pollution arising from the release of lead to the environment from shotgun pellets. However, cormorant carcases can be usefully used for post mortem analysis (e.g. to provide information on diet at different sites), and the use of lead in shotgun cartridges for waterfowl hunting has recently been banned in the EU.

It is also worth noting that if licensed hunters are used to shoot cormorants, conflicts of interest can occur. For example, during the initial part of the shooting season, when cormorant numbers first build up, hunters may not wish to target cormorants for fear of deterring their preferred quarry (ducks and other waterfowl), even though cormorant predation may be significant then. In Italy, it has been observed that cormorant shooting may therefore be restricted to short but intense periods towards the end of the shooting season — i.e. after the birds have already caused considerable damage to fish stocks.

5 FINANCIAL COMPENSATION

Financial compensation is used in some countries to offset the consequences of cormorant predation for particular stakeholder groups. Such measures are largely, but not exclusively, restricted to fish farms and hatcheries, with losses of fish consumed by cormorants being covered (though not always fully) by compensatory payments. Where compensation is paid for fish losses to cormorants, the actual loss of fish is seldom, if ever, calculated rigorously. Thus, the relationship between financial payments and the actual fish losses being incurred is usually no more than an estimated guess. This is the result of the inherent difficulties in accurately quantifying the impact of cormorants on fish stocks or catches. In some regions no real attempt is made to quantify fish losses, rather a sum of money is set aside for compensation payments and this is shared (sometimes equally, sometimes not) amongst all legitimate claimants. In some countries it has also been possible to apply for financial aid for the construction of netting enclosures or for scaring programmes.

Many authorities take the view that the cost of managing cormorant conflicts should be borne by the affected stakeholders. Thus, financial compensation arrangements are generally considered inappropriate. In terms of efficacy, the payment of compensation for fish losses will do nothing practical to reduce other aspects of how cormorant-fisheries conflicts are perceived (e.g. birds will still be eating and/or damaging the fish) and might, arguably, be considered to make the situation worse on the grounds that there might be less incentive for stakeholders to implement any active deterrent measures. There may be a stronger argument, then, for financial support for other measures, such as building enclosures, where such approaches might be realistic. Compensation would undoubtedly be seen as acceptable for some affected stakeholder groups. However, it seems unlikely that such schemes will be adopted widely.

There are active schemes of financial compensation for damage caused by cormorants in several EU countries — Czech Republic, Germany (Saxony), Latvia, Romania, Slovakia, Finland, Lithuania and Belgium (Wallonia). The compensation schemes and procedures vary, and the authority responsible for this issue may differ — in some countries a central government ministry is responsible whereas in others the responsibility rests with a local authority.

Also, there are differences in the legislation regarding what is eligible for compensation. In some cases, this is available only for fish stocks on fish farms, fish hatcheries and fish breeding and keeping facilities. Further, compensation applies only for dead fish in some countries, whereas in others compensation is available for injured fish and for the associated expenses (disposal of carcases, veterinary fees, etc).

Other forms of financial support exist under the European Fisheries Fund (EFF), which forms part of the European Common Fisheries Policy. Its objective is to provide for exploitation of living aquatic resources and aquaculture in the context of sustainable development, taking account of environmental, economic and social aspects in a balanced manner. The support is available under the 'aqua-environmental measures' and financed by the EU. It is available to every Member State of the European Union in compliance with Council Regulation (EC) No 1198/2006.

The 'aqua-environmental measures', which apply under Article 30(2)(a) of the EFF, aim to promote aquaculture production methods that are sensitive to environmental and conservation issues; they can also be used to help address cormorant-fishery conflicts. They cover four different types of measures:

- Forms of aquaculture that provide protection and enhancement of the environment.
- Aquaculture operations that participate in EMAS (Community eco-management and audit system).

- Organic aquaculture.
- Sustainable aquaculture compatible with Natura 2000.

Compensation under this scheme may include: costs associated with high or frequent maintenance of farming structures; losses arising from predation by protected wild species (such as cormorants); and loss of revenue due to the requirement to maintain low stock densities (on environmental grounds). Owners of fish pond farms that fulfill certain environmental criteria are eligible for annual payments, per hectare of pond area.

Under Article 29 of the EFF, financial support can be also be provided to aid investment in the purchase of equipment used for protecting fish pond farms from wild predators.

Country Examples

The number of complaints about cormorant damage from fish pond farmers in Latvia fell to zero in 2008 following the adoption (in November 2007) of a compensation scheme by the Latvian Government.

In Saxony, Germany, fish farmers have been paid compensation since 1996 to help maintain and sustainably manage Carp ponds along traditional lines. In addition, compensation may be provided for especially high damage to fish in fish ponds.

In the Czech Republic fish losses in ponds are calculated by multiplying cormorant numbers and the number of days the birds are present — verified by an independent expert or ornithologist — by an average daily food requirement for each cormorant (500g per day) and the market price of the fish. Compensation is available mostly in the larger fish pond regions located in South Bohemia and South Moravia, and this accounts for up to 85% of the total compensation payments for the whole country.

In Italy, financial compensation for cormorant predation on fish is provided by regional administrations, as it is for damage caused by other protected fauna. When regional administrations delegate this task to provinces (e.g. in Emilia-Romagna), the money is drawn from regional sources and has to be shared by all the provinces in that region. Provinces may have a duty to carry out bird or animal censuses, check for and log complaints and calculate the amount of compensation that should be provided. Because of financial constraints, reimbursement for the full economic impacts of pest species has been replaced by contributory compensation, where only part of the estimated costs are met. In the case of damage caused by protected species, compensatory payments are provided by the local administration, whereas for game species this duty is performed by the statutory organisations that manage hunting areas at provincial level, using funds derived from hunting licences.

In Slovakia, a compensation scheme has applied since 2002 when a new Nature and Landscape Protection Act came into force. This only relates to damage caused by cormorants at fish rearing and breeding facilities, with compensation payments being provided by the Ministry of Environment. Fish losses are estimated by official experts on a case by case basis. Between 2003 and 2006, 3,696,723 SKK (approximately 122,000 Euro) was paid out, representing around 40% of all the money paid out under compensation schemes for damage caused by protected species (brown bear, wolf, lynx, otter, European bison, beaver and grey heron).

6 CASE STUDIES

As discussed throughout the Toolbox, cormorant management techniques can be applied over very different temporal and spatial scales. At one extreme there are very localised, short-term, site-specific measures and, at the other, the potential for long-term population control measures at the pan European level. In practice, management quite often applies at scales intermediate to these, with programmes being established, agreed and coordinated over a wider, but still relatively local area.

Fishing station — Lake Kerkini, Greece.
Photo courtesy of G Catsadorakis.

The following case studies help illustrate the use of cormorant management techniques at different scales and they highlight some of the complexities and difficulties that can affect management programmes. These range from relatively small scale, site-specific examples and targeted trials to larger, programmes coordinated over wider areas and national management plans. This section places more emphasis on the larger programmes and plans since much of the site- or technique-specific information has already been incorporated into the main section of the report (Section 4) outlining the various cormorant management tools. It is also true that where management measures are carried out by individuals or small organisations at local levels, there is rarely sufficient manpower or other resources to fully monitor the impact of the measures, compile data and analyse the effectiveness of the techniques.

6.1 Case Study No. 1. Greece — Local use of visual/ auditory deterrents to protect fishing sites on Lake Kerkini

For further details contact Savas Kazantzidis (savkaz@fri.gr)

A technique has been employed at Lake Kerkini in northern Greece, which combines visual deterrents (reflectors) with audible deterrents. In this example, preferred fishing sites close to the shore (<100 m), where fishermen place their fishing nets, are protected using a system of ropes supported by poles. Reflectors (tin plates and cans) and bells are hung along the ropes and, when cormorants approach the fishing site, fishermen on the shore pull the rope resulting in the movement of the bells and the reflectors. This technique is used during daylight hours throughout the year and requires the permanent presence of at least one person in the area. It is thus relatively costly in manpower terms, although is simple to install and operate and has relatively low material costs. The method is considered effective for these fishing sites close to the shore, with birds being scared from the area for a short period (typically a few hours).

6.2 Case Study No. 2. UK (England & Wales) — Protecting a locally endangered species involving management of a cormorant breeding colony

For further details contact Ian Winfield (ijw@ceh.ac.uk)

The Schelly (*Coregonus lavaretus*), a species of whitefish, is nationally rare in the UK. It is subject to

Schelly — from Haweswater, UK. Photo courtesy of Ian Winfield.

protection under the UK Wildlife and Countryside Act, 1981 and is on the List of Priority Species and Habitats under the UK Biodiversity Action Plan. The species is restricted to relatively few water bodies in the UK, including Haweswater, a large reservoir located in the English Lake District (North West England). Investigations in the 1990s indicated that the status of the Schelly population in Haweswater was very poor, both when compared with the contemporary status of other Schelly populations in England and Wales and when compared with its own earlier status in the 1960s. This deterioration was attributed to a number of factors and a range of conservation actions were instigated.

A cormorant breeding colony started to establish on the lake in 1992 and subsequent investigations indicated that the feeding activities of these birds were having a significant negative impact on the population of Schelly. These concerns led to the introduction of scaring procedures from 1999 onwards to restrict nesting and the production of young cormorants at the colony. However, the effects of these measures were limited and did not reduce the numbers of adult cormorants at the lake, which continued to pose a threat to the Schelly population. As a result, the management measures were extended from 2004 to 2007 to include the shooting of adult cormorants. Despite relatively few birds being shot (a total of 29 in the three years of shooting), with progressively fewer birds shot each year, these measures were successful in reducing cormorant impact.

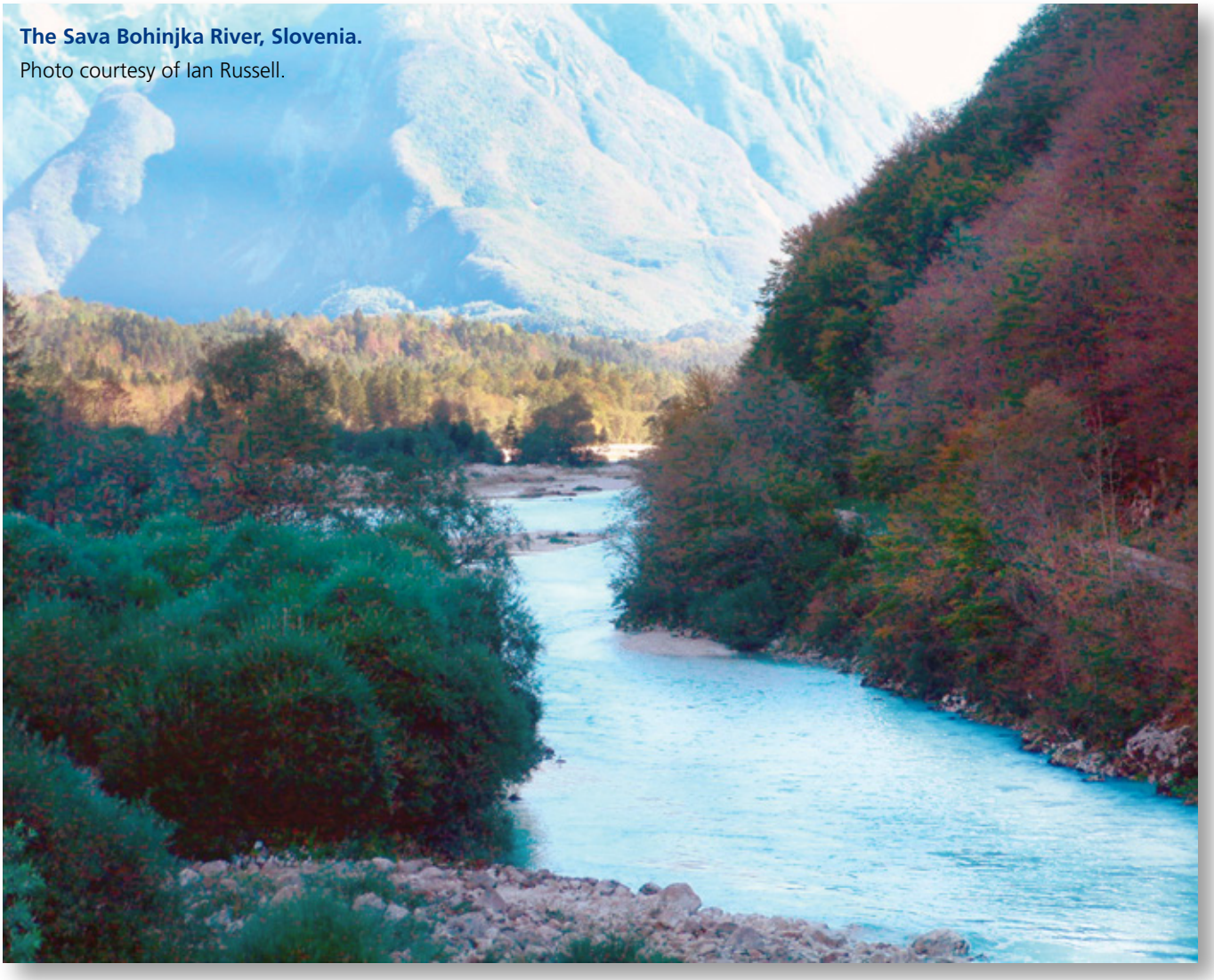
In 2007, the estimated level of predation over the whole of the year was only 19% of the 1997 level (population modelling has indicated that predation impact from cormorants should be reduced to 10% or less of the 1997 level to achieve a significant recovery of the Schelly population in the medium-term). Although shooting has not been undertaken since 2007 due to the low numbers of cormorants present at the lake, further management of the cormorant population may be needed, along with continued monitoring of the Schelly population.

6.3 Case Study No. 3. Slovenia — An example of collaborative shooting to protect a river fishery

For further details contact Marijan Govedic (marijan.govedic@ckff.si) or Miha Janc (miha.janc@siol.net)

The River Sava Bohinjka in north-west Slovenia has clear, oligotrophic water which drains from the oligotrophic Lake Bohinj and the surrounding Alpine mountains and flows eastwards to join the Sava River. It has a water area of approximately 1,000 ha and the main fish species are: Brown Trout, Rainbow Trout, Chub (*Leuciscus cephalus*) and Grayling. Due to the presence of dams, Nase (*Chondrostoma nasus*) and Danubian Salmon (*Hucho hucho*) are rare today. Angling and fly-fishing contribute to the income of the region, both directly from angling activities and indirectly from accommodation, food, etc. Reduction in the populations of sport fish may thus cause financial damage.

Within two winters of cormorant foraging in the Sava Bohinjka (about 200 birds each winter), the population of Grayling collapsed dramatically. The number of broodstock electric-fished from spawning sites on the river for use in stock enhancement programmes fell from 320 to zero over this period. These fish were collected in a fish reserve area where angling had not been permitted for more than 30 years. Electric fishing also indicated that the total Grayling population had declined by 95%. Although the cormorants' night roost was outside the Sava Bohinjka river valley,



The Sava Bohinjka River, Slovenia.
Photo courtesy of Ian Russell.

a few kilometres downstream of Radovljica, cormorants fed on the river because the lakes freeze over during the winter period.

Investigations indicated that:

- Cormorants were feeding on Grayling.
- None of the other biotic or abiotic parameters changed dramatically or varied more than in previous years and none, could account for the change in the fish population.
- There was no evidence of disease in the Grayling population.
- The Grayling population improved after the removal of the cormorants and stocking with more fish.

The legal scaring and shooting of cormorants on the Sava Bohinjka over two successive winters cost two angling clubs 12,000€ and 15,000€, respectively, for transportation, ammunition and overheads. During these two winters anglers devoted 6,300 volunteer hours per annum to scaring the birds, and hunters spent 250 and 280 hours, respectively, on shooting the birds. Total annual costs for these actions in the whole valley were approximately 25,000€. Besides legal scaring and shooting, some illegal shooting of the birds (in excess of the allocated totals) is thought to have taken place. Cormorants are still present on the main Sava River every winter, but they continue to be regularly scared away from its tributary — Sava Bohinjka.

In this conflict a small number of cormorants (about 200) were perceived as the direct cause of severe damage on a regional scale. Cormorant predation on the Sava Bohinjka River represents a quite distinct type of conflict, but one that commonly occurs on relatively small, sub-alpine salmonid rivers. Such rivers become favoured cormorant foraging locations, due to

the freezing over of many adjacent stillwaters, and the common prey species at these sites are of high recreational and amenity value.

6.4 Case Study No. 4. Germany — Wires over Carp ponds

For further details contact Thomas Keller (thomas.keller@reg-ufr.bayern.de)

In one of the more comprehensive and effective tests at a German fish farm, wires deployed in a regular grid pattern (5 m, 7.5 m and 10 m spacing) on a series of eight ponds reduced over-winter fish losses from 88% (in the winter before protection) to about 10% in the following year. During the trial, 113 cormorants were recorded over a period of 27 days at the farm, but none were observed to land on the ponds once wires were in place. In another trial, Carp losses were found to be 2.5% in a protected pond (wires spaced at 7.5 m intervals) compared with 61% in an adjacent, unprotected pond. However, no benefits were apparent for the other fish species in these ponds. In a further trial, overhead wires at 10m spacing had no apparent effect on summer fish losses, which remained high (>70%) in the vicinity of a cormorant breeding colony.

Parallel wires over a Carp pond, Germany. Photo courtesy of Thomas Keller.

6.5 Case Study No. 5. Greece — Netting enclosures to protect over-winter fish-holding facilities

For further details contact Manos Koutrakis (manosk@inale.gr)

In Greece, the Porto-Lagos Lagoon and Vistonis Lake estuarine system is an ecologically important wetland, comprising part of the East Macedonia and Thrace National Park and one of ten Greek wetlands protected by the Ramsar Convention. It is also of importance as a fishery, with more than 500 t of commercially important fish species landed per year. Market-sized individuals are harvested during their reproductive migration to the sea at a specially designed trap situated at the southern end of the estuarine system. Smaller fish caught in the trap are either returned to the lagoon or are placed in artificial channels where they are kept for the winter months and then released again in the lagoon in order to grow until the next harvest period. The wintering channels are 1.5–2 km long, 30–40 m wide and 5–6 m deep and typically hold around 300 t of fish (mainly Grey Mullet, Mugilidae, but also Sea Bass [*Dicentrarchus labrax*] and Gilthead Sea Bream [*Sparus aurata*]). The high concentration of fish in these wintering channels attracts cormorants and can result in substantial losses for the fishermen who harvest these channels.

Over the last two decades, fishermen have tried various different techniques (e.g. gun shots, wires, other audible deterrents) to keep cormorants away from the channels. However, the current method is considered the most successful and cost effective, even though the cost was high. The channels are now covered completely by nets which are hung from central supports, with some supplementary shooting to deter birds from unprotected areas. The nets cost about 85,000€ and last for about four to six years, with additional annual maintenance costs, particularly to repair the part of the net that covers the channel bank, estimated at 10,000€.

Netting enclosures over fish wintering channels in the Porto Lagos Lagoon, Northern Greece.
Photos courtesy of Manos Koutrakis.

6.6 Case Study No. 6. Sweden — Fishery management measures to improve fishery performance on two large lakes in the presence of cormorants

For further details contact Erik Petersen (Erik.Petersson@fiskeriverket.se) and Henri Engström (Henri.Engstrom@ebc.uu.se)

Lake Hjälmaren is the fourth largest lake in Sweden (484 km^2). Cormorants started to breed on islands in the lake in the mid 1990's, with numbers increasing rapidly from 23 breeding pairs in 1996 to 1,278 by 2010 (Figure 5). The lake supports a commercial fishery, with Pikeperch (*Sander lucioperca*) and Signal Crayfish (*Pacifastacus leniusculus*) the two most important species. Cormorants were reported to have affected the fishery by decreasing catches of pikeperch and through the 'theft' of bait fish in the crayfish pots.

In response to the decreasing catches, a number of actions were taken in June 2001 to improve the Pikeperch fishery:

- The minimum landing size was increased from 40 cm to 45 cm;
- The minimum mesh size of the nets was increased from 50 mm to 60 mm; and
- Improved handling methods were introduced to allow catches to be processed more effectively (trap net and gill net caught fish were brought to the boat for processing at different times) and more rapidly (the use of a sorting table enabled undersize Pikeperch and other, non-target species to be more rapidly returned to the water, typically in around 30 seconds).

As a result of these measures, the Marine Stewardship Council (MSC) certified the Lake Hjälmaren fishery as a sustainable and well-managed fishery, the first inland fishery in the

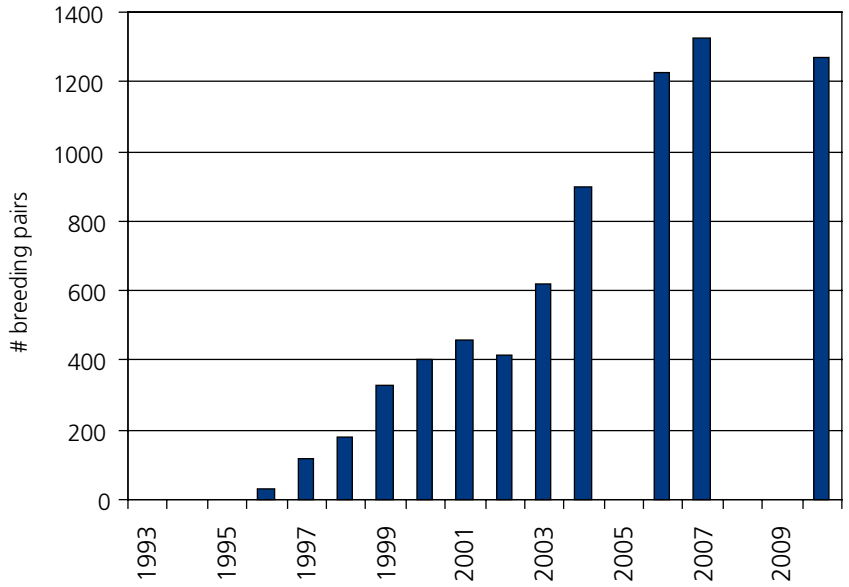


Figure 5 Number of cormorant breeding pairs on Lake Hjälmaren, southern Sweden, 1996–2010.

world to be recognised in this way. However, despite these measures, the fishermen found that cormorants were proving a particular problem for smaller 0+ and 1+ Pikeperch in the autumn. As a result, the regional government has given permission for birds to be shot during and after the breeding season. The number permitted increased each year up to 2004, but has remained stable at 1,650 birds since then (Figure 6). The goal of the shooting has been to protect fish at fishing gear and to keep the cormorant population at a low level (250–300 breeding pairs). However, the shooting has not obviously halted the cormorant population growth, probably because only a small proportion of the shot birds originated from the local breeding population. Furthermore, the permitted quotas have not been met in most years. The levelling off of the population in the most recent years probably reflects density dependence — i.e. the population being limited by available resources.

The problem of cormorants stealing bait fish from crayfish pots was found to be largely attributable to the design of the pots. Switching to an alternative design that the birds were unable to open largely solved this problem.

The number of breeding cormorant pairs on the nearby Lake Mälaren, the third largest lake in Sweden (1,140 km^2), showed a similar pattern of population development to that seen on Lake Hjälmaren (Figure 7). The lake supports a similar commercial fishery and catches on the two lakes have historically been more or less parallel. However, when the new measures were introduced on Lake Hjälmaren, the fishermen on Lake Mälaren refused to adopt similar measures, arguing that the lakes were too dissimilar.

The actions taken on Lake Hjälmaren have resulted in an increased yield of Pikeperch, despite the strongly increasing cormorant population. The mean yearly catch has increased from an average of 59 t in 1996 to 2000 to 153 t per year from 2001 to 2007. In contrast, the catch of Pikeperch on Lake Mälaren only increased from 132 t to 142 t over this period. In response to the perceived success of the fishery measures on Lake Hjälmaren, the fishermen on Lake Mälaren also introduced a minimum landing size and minimum mesh size for the Pikeperch fishery in 2008. A transition period of three years was also agreed, so that the new regulations will take full effect in 2011. Shooting of cormorants

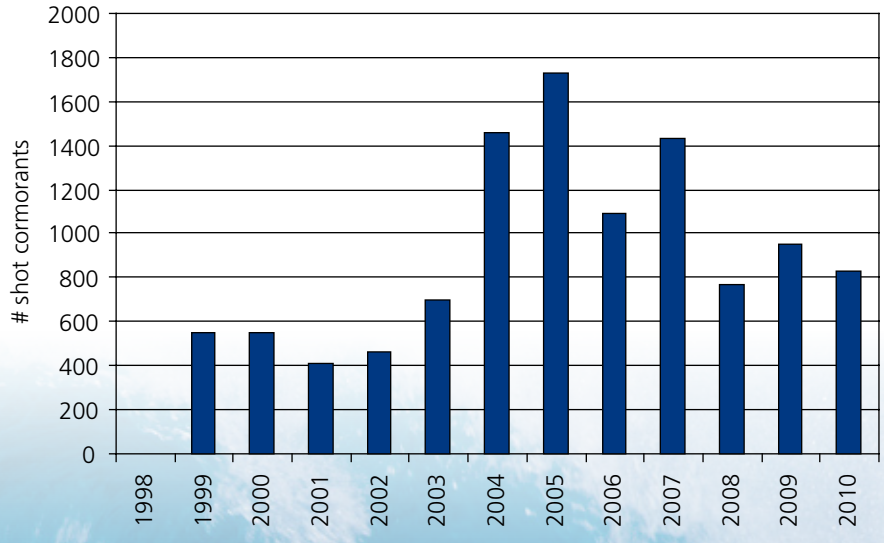


Figure 6 Number of cormorants shot each autumn on Lake Hjälmaren, 1999–2010.

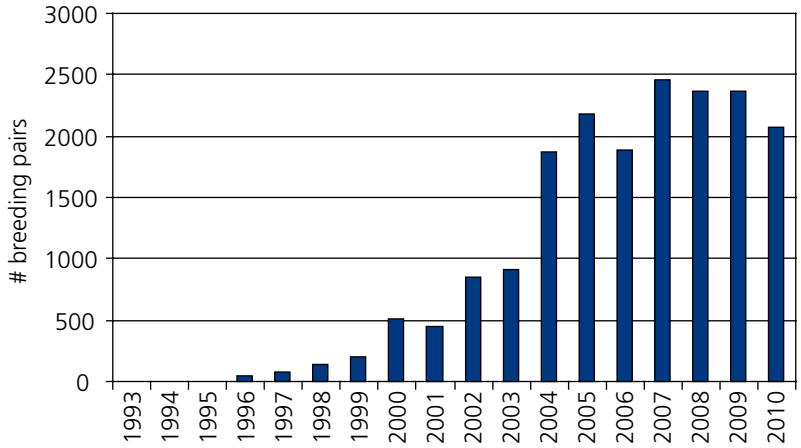


Figure 7 Number of cormorant breeding pairs on Lake Mälaren, southern Sweden, 1994–2010.

to protect fisheries is also allowed at Lake Mälaren, but on a smaller scale to that on Lake Hjälmaren. One reason for this is the structure of the lake, which has many small, elongated bays. This makes coordinated shooting difficult and means birds can more easily find safe places to feed and roost when disturbed.

6.7 Case Study No. 7. Israel — Coordinated cormorant management on a relatively large scale in the Hula Valley

For further details contact Tamir Strod (tst737@gmail.com)

In the Hula Valley, in northern Israel, about 8,000–9,000 cormorants used to over-winter each year, with the birds causing major conflicts at fish ponds managed for aquaculture. Hundreds of cormorants were shot every winter over a period of seven years, but the problem essentially remained at about the same intensity. The shooting was costly and seemed to be largely ineffective. It also polluted the environment, both as a result of the release of lead shot and the presence of bird carcases.

In response to this perceived failure, a collaborative partnership involving biologists, fish farmers and NGOs developed a co-operative management scheme for the Hula Valley that operated from the winter of 2001–2 to the winter of 2004–5. Deterring cormorants from fish ponds was organised in a coordinated manner and was informed by the best available science and up-to-date information on both the fish stocks and the cormorant population, in particular, total numbers and distribution of birds at foraging sites. Scaring commenced as soon as the birds first appeared in the area in late October and was carried out every morning when the first cormorants arrived to forage in the fish ponds. Under the scheme, shooting to scare and the use of different types of fireworks and pyrotechnic devices, with a range of effects, largely replaced lethal shooting. Scaring was carried out by a team of three professional hunters from early December to late February, with additional help provided by up to three fish farmers as necessary. All the ammunition and fireworks were bought collectively and monitored to reduce expenses (considered a major part of the conflict).

The deterrent actions were initially focused on fish ponds holding *Tilapia* species rather than more economically important fishes, since earlier experimental trials under controlled conditions demonstrated these were a preferred prey of cormorants. Subsequent stomach analysis of shot birds revealed that approximately 95% of the prey comprised *Tilapia zillii* and indicated that financial losses were far less than those perceived by fish farmers. *Tilapia zillii* are often seen as a pest species in carp ponds, where they can compete with carp for oxygen, food and space.

Over three consecutive winters, the level of deterrence, manpower and ammunition was progressively reduced, such that by winter 2003–04 only one professional hunter was employed from mid-December to mid-February, assisted by up to three fish farmers between early December and mid-January. This saved money and reduced the use of cartridges by at least 60%.

As a result of these management measures over three consecutive winters, the peak seasonal numbers of cormorants feeding at the fish ponds declined from about 3,600 birds in December 2001 to around 200 to 300 in December 2004, while peak seasonal numbers roosting in the Hula Valley declined from 8,150 in December 2001 to 1,250 in December 2004. The

Mobile gas cannon and shooting, Israel. Photos courtesy of Ian Russell and Jonathan Harari.

birds moved to other foraging and roosting sites well away from the aquaculture production areas and losses of fish from the fish ponds declined markedly. Moreover, the operating costs (e.g. staff time, ammunition) for the fish farmers also reduced by about 80%. Consequently, the conflict with the cormorants was perceived as less of an issue each year.

Coupled with the availability of alternative foraging sites for cormorants, including the Sea of Galilee, the key to the success of the Hula Valley scheme was:

- **Organisation** — coordinating interest/expert groups, manpower and resources. All actions were pre-arranged, coordinated and monitored over the whole region, to avoid simply scaring the birds from one fish farm to another. The monitoring was carried out on a daily/weekly basis to ensure rapid feedback and effective targeting of activities.
- **Information** — basing decisions on knowledge about cormorant physiology and ecology, actual numbers of cormorants and their movements, fish stock assessments, damage assessments, etc. This enabled the actions to be focused at the 'hotspots' — i.e. those fish ponds that were particularly attractive to cormorants or very sensitive to damage — instead of over a wider area.
- **Timing** — actions started as soon as the cormorants first appeared in the region (late October) and were carried out every morning from the moment cormorants first arrived at the fish ponds.

However, there was some deterioration in the situation subsequently. As a result of the perception, at the end of winter 2004–5, that the problem with cormorants was relatively low, coupled with changes to the fish farmers working in the area, cooperation between farmers and coordination of the management plan became less effective. Consequently, the number of cormorants (both roosting and foraging) increased in the following two winters (2006-07 and 2007-08). This highlights the importance of ensuring that the use of deterrents is both sustained and coordinated.

6.8 Case Study No 8. Germany, Bavaria — relatively large-scale lethal techniques as examples of cormorant population control in practice

For further details contact Thomas Keller (thomas.keller@reg-ufr.bayern.de)

Cormorant culling in Bavaria, southern Germany (mostly during the winter migration in August–March) began in 1995 and developed subsequently through various State regulations and legislation from the Bavarian State Government. Although 2,547–8,724 cormorants were shot each winter — sometimes in greater numbers than the average number counted during regular surveys — the number of birds wintering in Bavaria has remained remarkably stable (Figure 8). Furthermore, since shooting began, the number of night roosts

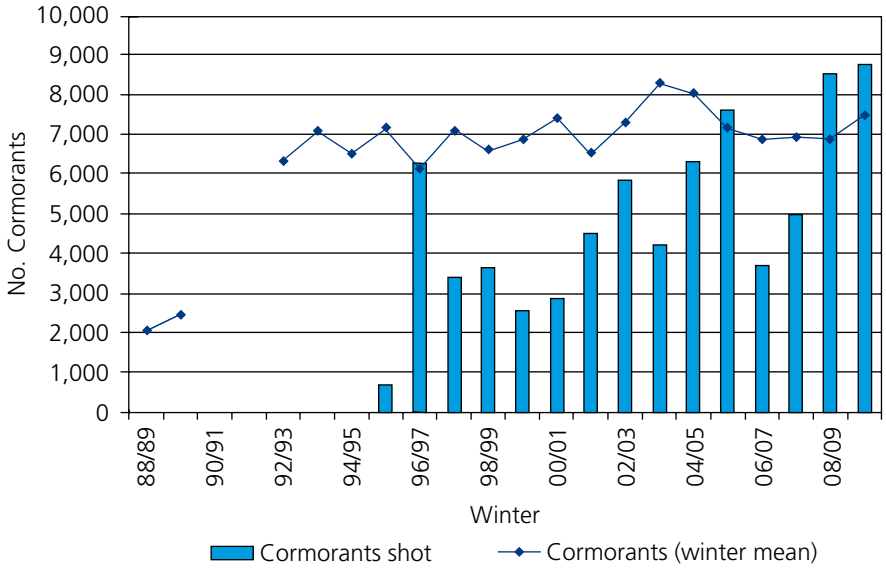


Figure 8 Mean cormorant numbers between October and March, and numbers of birds shot in Bavaria in the winters of 1988/89 to 2009/10 (Data: LBV).

in Bavaria has increased. Most of the birds were shot at large rivers, followed by ponds, small rivers and gravel pits. It was concluded that this uncoordinated shooting of cormorants over more than fourteen winters did not reduce the overall, nor the regional numbers of birds wintering throughout Bavaria. It therefore appears that there must be a high turnover of migratory birds through Bavaria, even in mid-winter.

Since cormorant numbers were not reduced, there was no reason to believe that there was a reduction in the amount of fish being consumed. However, the number of cormorant night roosts in Bavaria increased during the years of shooting, suggesting that birds may now be more evenly distributed in the area than before. The overall goal of reducing the total amount of fish consumed by cormorants in Bavaria was not met through intensive shooting in winter. Similar experiences are reported in France — see Case Study 9.

6.9 Case Study No 9. France — Large-scale shooting of wintering cormorants

For further details contact Loïc Marion (loic.marion@univ-rennes1.fr)

In less than two decades, France became the largest wintering cormorant area in Europe, with most of these birds using inland waters. This generated strong conflict with fish farmers in the five main fish-pond areas (Dombes, Forez, Brenne, Lorraine and Vendée) and with anglers over a wide area, particularly on rivers. In spite of conflicting views regarding the extent to which cormorants were causing serious damage at a large geographical scale, shooting started in France in 1992 during the over-wintering season (October-March). Initially, this was only at a few sites, but it increased rapidly from 4,500 birds shot in 1996–97 to 33,000 birds, extending over a large part of France, by 2008–09 (Figure 9). France is thus currently the area in Europe where most cormorants are shot.

Shooting is controlled by the French national authorities, who set annual quotas for each administrative area (département). Initially, these quotas were set at a level that represented about 12% of the wintering cormorants in mid-January (from official counts), and were only allocated where conflicts occurred in fish-ponds. Fish farmers also had to declare the number of cormorants shot during the preceding winter in order to qualify for a shooting permit. However, since no effect was observed in the number of wintering cormorants, shooting was later extended to other open water bodies, and quotas were allocated to 28 départements by 1997–98. Moreover, due to pressure on the authorities from anglers, quotas were also allocated for use by anglers on rivers, initially in 9 départements in 1997–98, and then progressively to a large part of the country. In 2008–09, 68 départements allowed shooting at fish-ponds or rivers out of a total of 93 départements with wintering cormorants (77 départements allowed shooting in 2006–07).

From 2006–07 the minimum number of cormorants permitted to be killed in a département under quota was increased to 150 from 90, with a total of 36,000 birds permitted for the country as a whole. The latter was increased to 41,800 in 2009–10 (Figure 9). In reality, not all these birds were killed, with numbers actually shot ranging from 32 to 4,361 in different départements, totalling 31,000 cormorants in all in 2006–07 and 33,000 in 2008–09 and 2009–10. This represents 31% in 2006–07 and 40% in 2008–09 of the wintering population counted in

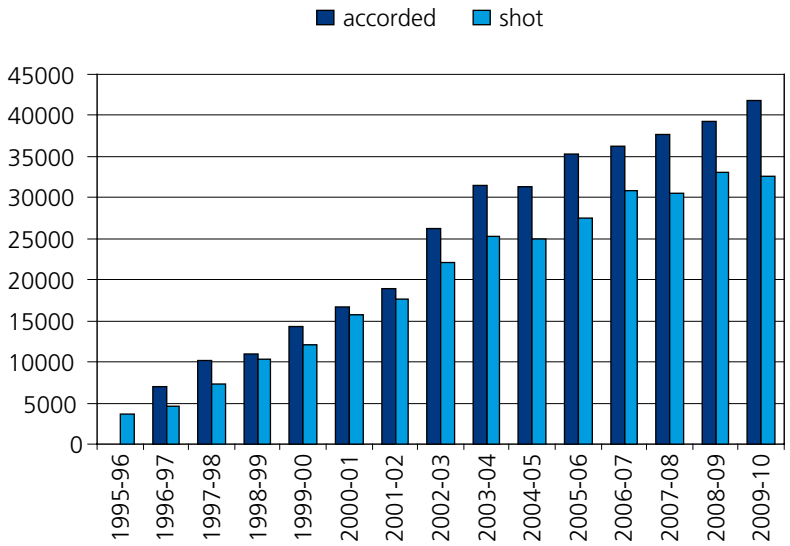


Figure 9 Numbers of cormorants permitted to be shot in France ('accorded') and numbers of birds shot over the winters 1995/96 to 2009/10.

mid-January, albeit most shooting occurs before this time.

In spite of this large-scale shooting, no effect has been observed on the number of wintering cormorants at a département scale (i.e. no correlation has been demonstrated between shooting intensity and trends in bird numbers), and progressive levelling-off of the national population since 1999 appears to be mainly due to natural density-dependent factors. The French national authorities, and many fish-farmers and anglers have come to the conclusion that shooting is largely ineffective, although they are reluctant to abandon existing lethal control measures pending some other solution. The current favoured proposal is the implementation of a wider pan-European scheme that would limit the cormorant breeding population in northern European countries and hence reduce the number of winter migrants in France.

As a result of the French national plan focussing on killing cormorants over the past 16 years, few other deterrent measures have been tested except at a very local scale, with no precise data about these. Moreover, shooting has been carried out throughout the country (mainly at night roosts in the vicinity of large- or medium-sized rivers and, less frequently, at fish-ponds during the day), without any real strategy to protect specific water bodies. Thus, no efforts have been made to preferentially protect small rivers or ponds and allow cormorants to preferentially use large rivers or lakes where impacts may be less of a concern.

6.10 Case Study No 10. Czech Republic — Shooting to control population growth and expansion

For further details contact Petr Musil (p.musil@post.cz)

Great Cormorants have been breeding in the Czech Republic since the 1980s. In South Moravia (district of Břeclav), the first breeding colony (32 pairs) established on the Nové Mlýny Reservoirs in 1982. The numbers of breeding pairs at this site peaked in 1991 (612 pairs) but decreased in subsequent years, probably due to the falling of some dead trees (roost sites) and the effect of shooting in both the pre- and post-breeding period. This colony moved to an alternative site near the Křivé Jezero National Nature Reserve in the late 1990s, with the population

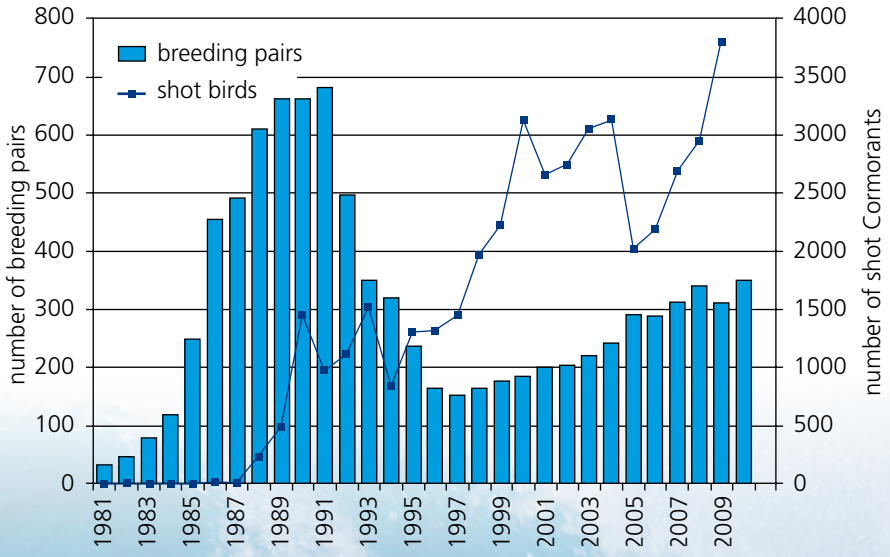


Figure 10 Numbers of breeding pairs and numbers of birds shot in the Czech Republic between 1981 and 2010.

size increasing from five pairs in 1997 to 90 pairs in 2007.

In South Bohemia, first breeding was confirmed in 1983 in the Třeboň Biosphere Reserve (district of Jindřichův Hradec). The number of breeding pairs increased to 142 in 1988, fluctuated between 57 and 119 pairs between 1989 and 2002, then increased again from 2003 to 2005 to over 200 pairs. More recently, the breeding population has been relatively stable (178 to 217 pairs between 2005 and 2010). The total breeding population in the whole Czech Republic has therefore fluctuated between 288 and 350 pairs between 2005 and 2010. The population is quite productive, with an annual mean production of young of 2.6 to 3.6 fledglings per nest.

The Great Cormorant is a protected species in the Czech Republic, but exemptions permit flushing and/or shooting of the birds under licence. Shooting is not allowed in the vicinity of the breeding colonies during the breeding season (from the end of April to mid-July) but is otherwise permitted. The number of cormorants shot increased sharply from 1980 to 2000, but remained relatively consistent after this date before a further rise in 2009 (Figure 10). Between 2000 and 2009 the number of birds shot has fluctuated between 2,000 and 3,800. Some fishery companies have encouraged shooting by paying a sum of about 300CZK (Czech crowns) (1€ = 24.5CZK) to hunters for every bird killed.

The most intensive shooting of Great Cormorants has occurred in the districts of Jindřichův Hradec and Břeclav, i.e. within 30 km of the breeding colonies, and this has accounted for around 70% of all the birds shot in the Czech Republic. The recovery of birds ringed in Czech colonies has shown that these have a high level of fidelity to the Czech breeding areas. In total, 104 of 111 recoveries (93.7%) of Cormorants ringed in Czech colonies, which were later recorded within the Czech Republic, were found within 30 km of the breeding colonies. Thus, while shooting was originally aimed at what were thought to be migratory cormorants, recovery data suggest that shooting probably has an important effect on the local breeding population.

6.11 Case Study No. 11. Switzerland — National cormorant management plan — scaring birds and preventing colonisation

For further details contact Verena Keller (verena.keller@vogelwarte.ch)

The Swiss authorities have adopted a programme of measures to safeguard particularly valuable riverine fisheries, in particular the locally endangered Grayling. Thus, protection of threatened fish species was the main argument for taking action against cormorants rather than damage to fisheries in a wider context. A Swiss Cormorant Action Plan was originally established in 1995, and this was subsequently reviewed and a new plan agreed in 2005. A broad-based working group 'Cormorant and Fisheries' set up by the Federal Office for the Environment (FOEN) participated in drafting the Action Plan and seeking consensus. This group comprised: federal and regional agencies responsible for fishing, hunting and bird protection; fish and ornithological research institutes; and angling, commercial fishing, nature conservation and bird protection interests. With the exception of the professional fishermen, all participants agreed with the 2005 Action Plan. The Action Plan also provided the basis for regulating the shooting of cormorants by the various cantons (regions) as, in contrast to the European Union, cormorants can be legally hunted in Switzerland during the normal open season for water birds.

The 1995 Action Plan defined three types of Swiss waters as a basis for management in the winter:

- Rivers and small lakes with an area of up to 50 ha (intervention areas), in which protection of fish has priority and consequently cormorant shooting/scaring is permitted (with three levels of intensity depending on the importance of the resident fish stocks).
- Lakes with an area of over 50 ha and dammed river sections (non-intervention areas), in which the protection of concentrations of over-wintering water birds has priority and consequently shooting/scaring of cormorants is controlled/ prohibited to avoid disturbance of water birds (with three levels of intensity, depending on the importance of over-wintering birds). Exceptions concern shooting, with special permits, of cormorants close to fishing nets in the case of damage to nets.
- Waters which have overlapping fishing and bird protection interests (overlap areas), leading

to scaring measures in certain lake areas (e.g. shooting of cormorants near the nets of professional fishermen), but the cessation of scaring measures on certain river sections (e.g. sites of importance for water birds on rivers).

In general, the 1995 Action Plan was considered to have been a success and was implemented in all regions where significant cormorant numbers had occurred. However, maintaining the labour-intensive scaring measures in the long term was considered to pose a problem. As far as achievement of objectives was concerned (improving the protection of fish and fisheries by reducing predation by cormorants in certain water courses while not affecting waterbird conservation) the 1995 Action Plan resulted in fewer cormorants moving onto river systems, reducing the effect on resident fish stocks, while birds over wintering on the large lakes were not disturbed by scaring measures against cormorants. However, in the overlap area on the Upper Rhine, it was felt that greater care was needed to ensure that deterrent measures (and other disturbances) did not have negative effects on other waterbirds in this internationally important water bird reserve.

The framework conditions for the 2005 Swiss Action Plan assumed that:

- The consistently high breeding numbers in northern Europe will continue to lead to a winter cormorant population of some 5,500 birds on Swiss waters.
- The number of over-summering cormorants (without management) will rise and lead to more widespread and larger breeding colonies in Switzerland and adjacent areas in neighbouring countries.
- No pan-European Action Plan will be applied in the next few years, which would affect cormorant numbers in Switzerland.


Photograph — Shutterstock

Thus, the provisions for continuing cormorant management during the winter were maintained. The 2005 Action Plan laid down the following as a basis for management in the summer:

- In intervention areas, cormorants starting to establish breeding colonies and flying in to feed are scared away.
- In non-intervention areas, cormorants are allowed to enter and establish breeding colonies undisturbed.

As the spatial and temporal dynamics of the formation of breeding colonies, and the number of over-summering cormorants, cannot be predicted, and there were fears in the fishery sector of uncontrolled growth in cormorant numbers, a Conflict Resolution Committee was set up. This consisted of one representative each from FOEN, the 'Schweizerischer Fischerei-Verband' (the Swiss Fishing Association), the 'Schweizer Vogelschutz SVS/ BirdLife Schweiz' (BirdLife Switzerland) along with regional representatives. This Committee was to meet when one of the following trigger criteria applied:

- The number of breeding colonies in Switzerland has increased to five or more, or the number of colonies on the same lake or in the same canton is more than two.
- The number of breeding cormorants in Switzerland has risen to 100 or more breeding pairs.
- The damage to nets of commercial fishermen on a lake has reached an unacceptably high level, based

on a joint assessment by the commercial fishermen and the regional fisheries agency. [It is recognised that cormorants adversely affect the commercial fishery on certain lakes. The birds take fish from the nets, thereby tearing holes in them, and professional fishermen have to alter their working hours in order to set and recover nets during periods of the day when cormorants are not active. There is no obvious means of avoiding these problems.]

- A member of the working group 'Cormorant and Fisheries' reports an extraordinary, regional problem in an intervention, non-intervention or overlap area.

Full details of the Swiss management plan (in German, with an English summary) is available from the following web address: http://www.news-service.admin.ch/NSBSubscriber/message/attachments/371.pdf

The Action Plan as it applies to the situation in winter has not been contested, and around 1,000 cormorants are shot each year. However, the agreed Action Plan for summer has come under pressure and been subject to debate. Cormorants started to breed in Switzerland in 2001 and when the management plan was adopted in 2005, the threshold of 100 breeding pairs for convening the Conflict Resolution Committee had already been reached. The Committee subsequently met twice but did not come to an agreement. For fishery stakeholders, the threshold of 100 breeding pairs had often been cited as a level for triggering intervention at breeding colonies, but this was contested by the bird conservation societies who advocated sticking with the agreement to apply the system of intervention and non-intervention areas.

So far, all breeding colonies (six colonies with a total of 547 breeding pairs in 2009) have been established in non-intervention areas and, to date, no measures have been taken at these sites. However, with the continuing increase in the oldest and largest colony on Lake Neuchâtel, pressure from the fisheries associations (both commercial and angling) has increased to destroy part of the colony. In this instance, and in contrast to the Action Plan, damage to fisheries and not protection of threatened fish species is the main argument for taking action. There is strong opposition from nature conservation societies to such action, in particular because the colonies are situated in water bird reserves. In 2009, the federal government changed the legislation to allow management measures (in particular oiling of eggs) in federal waterbird reserves of national and international importance to reduce damage to fisheries. No intervention has taken place so far because in 2011 the federal administrative tribunal accepted an appeal by nature conservation associations against the first authorisation issued by the department of environment.

As the revised management plan has not been accepted by all parties involved, in particular with regard to management during the breeding season, the Department of Environment dissolved the cormorant working group in 2009.

6.12 Case Study No. 12. Denmark — National cormorant management plan — local actions and reduction of breeding output

For further details contact Henrik Lykke Sørensen (HLS@sns.dk)

A cormorant management plan was first issued in Denmark in 1992 by the Ministry of the Environment in response to the marked increase in the breeding population of cormorants. This followed the introduction of measures to protect the species, from 1980 in Denmark

Cormorants on pound net, Denmark. Photo courtesy of Steffen Ortmann.

and 1981 in the remainder of the EU, subsequent to the Birds Directive. The increasing population led to numerous complaints from Danish fishermen and reports of reduced catches and cormorant damage to fishing gear. It resulted in the formulation of a national cormorant management plan.

The current management plan was approved in 2010, with the main objective of ensuring that the size and distribution of the cormorant population did not cause unacceptable damage to fish populations and fisheries, while maintaining the cormorant's protection and survival as a Danish breeding bird. The plan is designed to provide the Danish Nature Agency with the best possible tools to manage cormorant populations in respect of this objective.

The plan:

- Describes the present status of the cormorant population in Denmark and the conflicts caused by cormorants;
- Describes the experiences with different management tools;
- Lays down guidelines for regulation;
- Identifies the expected effect of the Management Plan; and describes the internal allocation of responsibility within the Danish Nature Agency.

The management plan also includes requirements for the continued monitoring of the cormorant population with a view to ensuring that the conservation status of the species remains satisfactory. The plan provides for a range of management tools to be used in resolving cormorant-fishery conflicts:

Technical measures — Modification of pound nets (Section 4.2.1) in order to make it more difficult for cormorants to catch fish inside the 'pot' of the net has been used with some success. However, the technique is not widely applied due to the extra work involved in modifying the nets and the negative effect of the modifications on subsequent catches.

Scaring of birds — Various methods are used to protect migrating smolts and fishing gear and to prevent the formation of new colonies. Shooting is the method most commonly used, sometimes in combination with other deterrents (e.g. gas cannons, fireworks, and other audible and visual scaring devices) to reinforce the effect of the scaring techniques.

Egg oiling — This is used to control unwanted population growth in certain defined regions. The effort is concentrated on sites in or close to important areas for fish or fisheries and is only used on ground-nesting colonies. In

Photograph — Shutterstock

recent years, the majority of eggs have been oiled in large colonies in Western and Northern Jutland in an attempt to reduce the number of cormorants foraging in the fjords in West Jutland. Egg oiling is believed to have a long-term effect on cormorant numbers at a local or regional level, but the effects can be variable (see Section 4.5.1).

Removal of nests to avoid new colonies — Nests are removed and birds harassed at certain breeding sites to prevent new colonies from becoming established.

Shooting at pound nets — The Danish Nature Agency can issue permits to owners of standing fishing gear to permit them to shoot (to kill) cormorants within 1000 m of standing fishing gear, precluding the breeding period from April to July. Around 4,000 birds are shot annually near standing fishing gear.

Shooting in the hunting season (autumn/winter) — A large research project on such shooting was reported in 2008 and was used to inform the review of the management plan and future policy decisions in Denmark. A brief summary of this work is provided in Section 4.5.2.

Fish farms — The Danish Nature Agency can issue permits to shoot cormorants within fish farm sites. The permit requires that other methods have been tried first. In practice, all the fish farms are protected by nets or wires and only a few birds are shot at these sites.

7 SUMMARY OF MANAGEMENT MEASURES

Cormorant-fishery conflicts are complex — they are seen in different ways by different stakeholders, and they affect a range of fishery sectors across a variety of aquatic habitats. Moreover, conflicts are also subject to change because of the population dynamics of both birds and fish; seasonal and annual variations in external factors (notably, weather conditions); alterations to the perception of the nature and severity of the conflicts; and the efficacy of management measures.

Managing such conflicts is also complex and influenced by wide-ranging factors, making it impossible to provide specific recommendations for different sectors or habitats, or to recommend a list of actions that could instantly solve any particular problem.

It should also be recognised that potential management tools will not always work to the satisfaction of any or all of those involved in a conflict. That said, there are numerous tools available and ample evidence that these can prove effective in some places at some times. Identifying the most appropriate deterrents or other mitigation techniques will require careful consideration by individual stakeholders, as will the decision on whether or not efforts may need to be coordinated over a wider area. In any event, those faced with addressing conflicts are strongly encouraged to experiment with different techniques and to be creative in devising mitigation programmes to best suit their individual needs.

Many of the available techniques work by persuading cormorants to leave a particular feeding site and move elsewhere. The birds' willingness to move will depend on both the severity of the persuasion to leave a site but also, and perhaps most importantly, on the relative attractiveness of alternative feeding/breeding sites in the area. Thus, the effective deployment of mitigation techniques at a specific location may depend on a good knowledge of a much wider area. Understanding the nature and extent of the problem being addressed will therefore be central to devising an appropriate mitigation programme.

Key issues to be considered will include:

- The size of the site to be protected and whether actions are to be local and site-specific or coordinated over a wider area.
- The nature and size of the problem being addressed (including the type of fishery, time of year, number of birds/fish involved, trends in bird/fish numbers, etc.).
- The behaviour of the cormorants (e.g. breeding, roosting, resident, migrating) and the availability of alternative foraging sites.
- The time that can be devoted to addressing the problem (deploying deterrents, coordinating actions, etc.)
- The associated costs (manpower and equipment) that can be devoted to addressing the problem viewed against expected fish losses (i.e. some sort of simple cost-benefit analysis).
- Awareness and adherence to local, national and international legislation on the use (or otherwise) of particular techniques, and the need to operate safely.
- Possible constraints on deterrent use such as: the proximity of human habitation and sensitive sites (e.g. airfields); the availability of electrical power; the security of unattended devices against possible theft and vandalism; accessibility to the land or water areas where deterrents could be deployed; and wider conservation concerns (e.g. any designated nature conservation status of a site and the potential impact upon other wildlife).

Individual managers will probably also need to consider the timescale over which management measures might need to be applied. Relatively few techniques offer potential one-off solutions to cormorant conflicts that might be effective in the long-term (years).

The two principle techniques that might provide such long term benefits appear to be:

1. The erection or installation of bird-proof barriers (typically on fish farms and perhaps small stillwaters) — techniques include netting enclosures, overhead wires and submerged, anti-predator nets.
2. Improvements to fish habitat in stillwaters and rivers — commonly, these may be the result of water quality improvements and general fishery management activities, although this might also include the use of artificial fish refuges at some smaller sites.

In contrast, a much larger number of techniques are effective at deterring cormorants in the short term, but they will probably require regular repetition, reinforcement and alteration to remain effective in the longer term. These include many of the deterrent techniques listed, as well as local reductions in cormorant populations, such as through shooting or the use of management measures at roosting or nesting sites. With many deterrents, their impact is likely to diminish with time as habituation tends to occur with any scaring technique that is not reinforced by a demonstration of actual danger. Thus, to be effective over longer periods, it is advisable to constantly change the appearance and location of devices, and to use combinations of harassment techniques in a rigorously applied, integrated control strategy. Shooting, too, is thought to be most effective where it is used in combination with other deterrent measures.

Techniques that require human presence are commonly regarded as the most effective deterrents, and those that carry biological significance and mimic threats known to birds tend to prove more effective and longer-lived than other novelty devices, although this should not deter experimentation and creativity in devising mitigation programmes. The frequency with which deterrents might need to be applied will also depend on the local situation. More frequent use will be required where there is a high degree of turnover of birds, to reinforce the scaring effect on birds newly arrived at the site and where there are fewer alternative feeding sites available for the birds.

As a general guide, it is likely that a cormorant management programme will need to be applied consistently and aggressively to be successful. Management measures should be started when birds first arrive, before they establish feeding habits at the water bodies to be protected. Thus, on waters that typically experience cormorant depredation in winter, a scaring programme should start in the autumn when the first birds arrive. Evidence suggests that cormorants stop visiting some water bodies for a month or more after initial aggressive scaring efforts and, since birds arriving later in the season often follow birds that are already present to feeding areas, conditioning the early birds to avoid certain waters should help to reduce damage by later arrivals. However, control measures may have to be applied consistently throughout the season at water bodies located on major daily flight paths, migration routes or near large roosting areas.

The application of management measures should also be timed to coincide as far as possible with the daily patterns of cormorant use at a site. Typically, birds feed at first light and this is likely to be the key period for applying deterrents, so that birds can be scared away from a site before they start to feed and begin to establish habitual feeding patterns. However, birds can feed at other times of day and may use a site for other purposes such as roosting or loafing. Regular patrols to monitor a site are therefore vital in targeting measures most effectively. When the potential for bird predation is at its worst, measures may need to be reinforced at regular intervals throughout the day from first light to dusk to be most effective. When birds only visit water bodies for certain periods of the day, such as morning and evening, employing scaring efforts only during those periods may be sufficient.

Managing conflicts is also likely to require striking an appropriate balance between the use of non-lethal deterrents and, where they are justifiable and approved, lethal measures. As noted previously, killing cormorants is very attractive to some stakeholders and commonly seen as taking positive action towards solving cormorant-fishery conflicts — one dead cormorant represents one less bird capable of eating fish. In practice, however, such killing may not deliver the anticipated ‘instant solution’ or the expected benefits. As a number of the case studies illustrate, shot birds can be replaced rapidly by birds from elsewhere, especially at attractive feeding sites or on migration routes, and large-scale shooting can prompt birds to become more widely distributed, thereby increasing the number of sites affected.

The Cormorant's mobility — between foraging sites and between wintering and breeding areas — and the species' flexibility — in nesting, roosting and foraging sites — means that protecting a fishery from them is very often not easy and may sometimes be impossible. Photograph — Shutterstock.

Even at a local scale, the success of shooting depends to a large extent on the nature of the local cormorant population, particularly the level of site fidelity and rate of turnover, but is also influenced by factors such as the site characteristics, the shooting strategy and the availability of alternative sites to which the birds can move. Both shooting and egg destruction can reduce the size of cormorant populations in an area, but the level of any reduction can vary, the results can be unpredictable and, where a reduction is seen, this can last for widely differing periods. Typically, effects are manifest over the longest term where a local population is relatively discrete, with limited turnover.

The concept of some form of pan-European cormorant population control is also attractive to some stakeholders. However, while the use of lethal control measures to address localised or short-term conflict issues is commonly seen as a necessary and acceptable management option, with general support from most stakeholder groups, large-scale population control at a national or pan-European scale is much more contentious. Although this is advocated by some stakeholders it is strongly contested by others. In reality, the complexities of shooting are likely to increase progressively as the scale of the shooting increases. Thus, the likelihood of achieving a successful, pre-determined outcome is progressively less likely.

Modelling suggests that some form of pan-European population control might be feasible, in principle. In practice, however, there are many biological reasons why attempts to reduce the continental cormorant population, and manage this around some lower 'acceptable' level, would be extremely difficult on such a broad scale. For example, the large territory, widespread breeding populations and further mixing and dispersing of the birds in winter means that there will be no simple relationship between management actions in breeding areas (e.g. in one country) and the consequences of these actions in wintering areas, or vice versa. Further, since numbers and distribution patterns of the birds are partly determined by density-dependent factors operating both within and outside the breeding season, the population as a whole has considerable potential to compensate for reductions in numbers.

For example, our knowledge of cormorant population dynamics indicates that a reduction in breeding birds in an area often leads to an increase in the numbers of young birds per nest that are fledged successfully. This is thought to be a consequence of the reduced competition among cormorants for food and the greater availability of fish with which they can feed their offspring. It is likely that the greater the (downwards) 'pressure' that is applied to reduce bird numbers, the stronger will be the (upwards) compensatory mechanisms that will operate to re-build population sizes.

One way of avoiding the problem of constantly fighting these compensatory mechanisms would be to work with density dependence and adopt a management approach whereby birds are restricted to a particular area and their expansion to other surrounding areas is controlled. In such a scenario, population size in the 'permitted' area would, in effect, become regulated by the available resources (e.g. food and breeding sites) and numbers would be expected to oscillate about some equilibrium or carrying capacity level. Active measures would be required outside this area — for

example, preventing new roosts establishing and the use of active deterrents at feeding sites — in order to restrict expansion. Of course, preventing such expansion of the population would not be easy, particularly at a larger scale. Nonetheless, such an approach may have applications in certain situations.

Even if successful, any reduction and stabilisation of the cormorant population at a lower level would reduce the overall impact of the birds on fish stocks and fisheries — fewer cormorants across Europe would eat fewer fish. However, it is highly unlikely that this would result in an even decline in the pressure on fisheries, as birds are likely to continue to favour high quality habitats that offer the best foraging potential. As fisheries that offer cormorants the best feeding opportunities are often those that are most valuable or desirable to fisheries stakeholders, there may be little diminution in conflicts even following a substantial reduction in cormorant numbers. Thus, although fewer birds should mean fewer fisheries with problems, conflicts are likely to persist at many sites, particularly the 'best' ones, unless a major reduction in cormorant numbers is achieved.

Aside from the biological issues, population reduction through culling, nest destruction or egg oiling raises practical, economical, political and ethical issues. Lethal measures are manpower intensive and costly, and there are practical issues to address over who funds any culling and who actually carries it out. This is of particular relevance because conflicts tend to occur at bird foraging sites where shooting is the only practical lethal control measure, whereas the control of cormorant populations at nesting sites is commonly required in countries other than where the conflicts actually occur. Control at nesting sites can also be problematic because these may be in inaccessible areas or on nature reserves; there may also be insurmountable, practical difficulties — egg oiling is not possible where the birds nest in trees, for example.

There are also concerns that should unregulated control be permitted, this could lead to sustained decline and possibly local extinction of cormorants. A coordinated, and appropriately regulated, pan-European population control plan might allay such concerns. However, the killing of any wildlife on a large scale will inevitably attract criticism and may not be publicly acceptable, and some governments are unlikely to allow such lethal measures to be initiated or extended in their countries. This would increase the cormorant quota that would have to be met by participating countries.

Regardless of any future initiative in relation to a possible pan-European plan, there will be an ongoing need to manage cormorant-fishery conflicts over various temporal and spatial scales. This, in turn, will require the use of appropriate management tools. It is therefore hoped that this **INTERCAFE Toolbox** will prove useful to stakeholders and managers in addressing such conflicts. It is recognised, of course, that the **Toolbox** in no way provides the definitive answer to these conflict issues.

It is anticipated that existing tools will be refined in the light of experience and that new tools and techniques will emerge. As noted at the outset of this summary, experimentation and innovation are likely to be the key drivers in developing techniques and management strategies for use in different situations. Continuing information exchange will also be vital in communicating findings and spreading good practice. In this context, it is hoped that the **INTERCAFE** website (www.intercafeproject.net) and a planned new cormorant web site hosted by the European Commission will provide an effective mechanism for exchanging ideas and experiences and ensuring ongoing, constructive dialogue between stakeholder groups.

Finally, it is important to remember that because cormorants feed on fish, the presence of any birds at a particular site has the potential to generate conflict between stakeholder groups. This **Toolbox** describes and evaluates the wide variety of techniques that are available to reduce the impact of cormorants on fish communities. It will help provide the means by which impacts can be reduced, but — ultimately — the resolution of conflict relies on the willingness of stakeholders to engage in that process. A range of stakeholders may have legitimate interests, particularly where conflicts occur at large fisheries or over extensive areas. The initiation and continuation of dialogue, and an appreciation and understanding among stakeholders of others' aspirations and concerns, are pre-requisites to resolving conflicts.

8 FURTHER INFORMATION

Worldwide, cormorants are among the most widely studied birds, and there is a huge body of literature on their biology, population dynamics and impacts on fisheries. The links below, though far from exhaustive, provide selected convenient sources of additional information on the methods that have been employed to control, exclude and manage the birds:

- **FACT Wildlife Management Group booklet: Protecting your fishery from Cormorants.** Web: http://www.naturalengland.org.uk/conservation/wildlife-management-licensing/leaflets.htm#piscivorous

- **Natural England advisory leaflet: Protecting fisheries from Cormorants — the use of fish refuges.** Web: http://www.naturalengland.org.uk/conservation/wildlife-management-licensing/leaflets.htm#piscivorous

- **Natural England advisory leaflet: Reducing the impact of fish-eating birds — the use of nets and wires.** Web: http://www.naturalengland.org.uk/conservation/wildlife-management-licensing/leaflets.htm#piscivorous

- **Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives. Bishop, McKay, Parrott and Allan.** Web: http://www.defra.gov.uk/environment/noise/research/birdscaring/birdscaring.pdf

- **Controlling Bird Predation at Aquaculture Facilities: Frightening Techniques. Southern Regional Aquaculture Center (USA).** Follow the 'Predators' link on the 'SRAC Fact Sheets' page at https://srac.tamu.edu this is document STAC0401

- **Control of Bird Predation at Aquaculture Facilities: Strategies and Cost Estimates. Southern Regional Aquaculture Center (USA).** Follow the 'Predators' link on the 'SRAC Fact Sheets' page at https://srac.tamu.edu this is document STAC0402

- **Wetlands International, Cormorant Research Group** official website: http://cormorants.freehostia.com/index.htm

- **EU Cormorant Platform** — a website through which DG Environment disseminates information about cormorants, cormorant numbers, management and conflicts related to cormorants, fish, fisheries and aquaculture. The Platform is developed as part of the work of the **EU 'CorMan' project ('Sustainable Management of Cormorant Populations')**. Web: http://ec.europa.eu/environment/nature/cormorants/home_en.htm

APPENDIX: WORK GROUP 2 MEMBERSHIP

The **INTERCAFE** Work Group 2 met and undertook work at each of the stakeholder meetings and during the between-meeting periods. Over the four-year span of **INTERCAFE**, the participants listed below attended some or all of the Group's meetings and contributed greatly to them. **INTERCAFE** participants from other Work Groups also made presentations and contributions to Work Group 2 meetings, but they are not named individually here.

Name	Affiliation & country
Thomas Keller (WG2 Chair)	Bavarian State Ministry of Environment, Public Health & Consumer Protection (StMUGV), Germany
Kareen Seiche (WG2 Vice-chair)	Saxon Ministry of Environment, Germany
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Oleg Nemenonok	Association of Fish Breeders of Latvia, Latvia
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Ian Russell	Centre for Environment, Fisheries & Aquaculture Science (Cefas), UK
Henrik Lykke Sørensen	Danish Forest and Nature Agency, Denmark
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