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