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,
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.

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
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
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
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

‘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.
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 use above and around the water surface.
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.

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.

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