13 SUMMARY AND SYNTHESIS

13.1 The Fishes-Cormorants-Human Fisheries triptych

This chapter summarises the facts, figures and implications derived from the discussions in the previous chapters and attempts to synthesise these into a coherent view of the ecological aspects within the Fishes-Cormorants-Human Fisheries triptych. The aim here is to summarise the ecological factors and mechanisms that play a role in the abundance and movements of birds and fish, and to relate these to the management practices of people in waters that are visited by Cormorants. For the three players in this triptych, conclusive factors are discussed before the relationships between them are sketched as a working model. At a later stage we plan to use this logical framework to quantify the relationships in order to forecast future developments.

13.1.1 Cormorant

As measured over the large sample of waters in **INTERCAFE's** database, the density of Cormorants expressed as average number per unit surface area is fairly constant. So, regardless of the size of surface waters, Cormorants spend, on average, about 10 bird-days per hectare per year at a site but can spend up to a maximum of 100 bird days per hectare per year. This use by Cormorants corresponds to roughly 4.5 kg (but up to 45 kg) of fish extracted per hectare of surface water annually. In waters poor in nutrients (oligotrophic and mesotrophic systems), peak standing stock of fish ranges from between 40–100 kg per hectare. In eutrophic systems this range is between 200–400 kg per hectare. Thus, based on these rather crude estimates, in most cases Cormorants take roughly not more than10% (and possibly up to a maximum of 20%) of the peak standing stock of fish. As such they are not much different from other avian fish predators (see synthesis in van Eerden (1997) for Great Crested Grebes (*Podiceps cristatus*), Goosanders (*Mergus merganser*) and Smew (*Mergus albellus*).

In water systems which have been exploited for a long time by both Cormorants and human predators (i.e. fishermen), the greatest proportion of fish mass there consists of young individuals, either of the current year or the previous one (the so-called 0+ and 1+ age-classes). Fish biomass generally correlates with Cormorant use of a foraging site, areas with higher fish abundance generally attracting more birds and/or birds remain there for a longer period. Most often this general relationship is associated with the trophic level of the water. In other words, the amount of nutrients in the water determines the level of fish production and this in turn governs Cormorant numbers. Cormorants can therefore be considered gross indicators of the trophic state of a water systems and, given the relatively small amount of fish taken by them, are not considered the prime factor that governs fish populations. In most natural and semi-natural systems, Cormorant numbers (and associated predation levels, incorporating the length of time the birds are present at a site) are dependent upon the 'available' fish biomass and not *vice versa*.

In accordance with this relationship, at a European scale most Cormorants are found in eutrophic, large-scale and rather shallow water systems. The bird population is thus likely to be determined by the available habitat, either in summer or in winter. Estuaries, large lake and shallow coastal systems are among the most frequently used habitats, followed by large rivers in winter. At the moment it is not possible to easily distinguish between any clear summer or winter foraging bottle-neck, which would be more important to set carrying capacity and thus determine overall numbers in the species. However, the extreme geographical spread in the Cormorant's winter range compared to that of the breeding range in summer suggests that, ultimately, the availability of ice-free foraging grounds (and associated fish stocks) in the winter period is likely to be limiting.

Preferred Cormorant foraging habitat consists of semi-turbid (Secchi depth 60–90 cm), relatively shallow (2–7 m deep) water with a high abundance of small fish (10–20 cm), within reasonable distance (<15 km) of a fixed place — either a colony where birds breed or a night roost. Cormorants are so called 'central place foragers' making foraging trips from a communal site. Roosts and colonies tend to be spread out regularly in the landscape in order to optimise the balance between the energy expended in flying to (and between) foraging sites and the energy gained through foraging. The Cormorants' 'harvest' of fish in natural waters is determined (besides by the availability of fish) by the foraging distance to and from the 'central place' (i.e the individual's current colony and/or roost site) and the presence and location of other roosts or colonies. Cormorants spend a lot of energy during diving, and so their energetic return needs to exceed this and thus food intake rate can not drop below a certain threshold. This threshold is obviously higher if energy expenditure increases (e.g. flight distance and/or diving depth increases and/or ambient temperature decreases). The same is true for breeding adults rearing young compared to birds having no nestlings to care for. The important conclusion here is that habitat conditions and physiological state ultimately govern Cormorant numbers through energetic rules. These energetic constraints limit Cormorants with respect to the potential extraction of prey fish. In typical Cormorant habitat the murky water conditions (by either suspended inorganic matter or algae) prevent the birds from obtaining higher prey yields than described above (often less than 10% of standing crop), even if the Cormorants have adopted social hunting in these circumstances (van Eerden & Voslamber 1995).

Cormorants are opportunistic foragers and do not select particular species of prey fish, their energy-expensive foraging behaviour meaning that they generally almost always eat the most abundant prey species that they can find. On a European scale, more than 100 fish species are regularly taken by Cormorants, with mid-water living Cyprinids such as Roach and Bream the most important group across Europe. These are followed by the Percids Perch and Ruffe and, in coastal waters, Eelpout, Viviparous Blenny, Gobies and Sculpins as the commonest prey. In smaller, fast-flowing rivers, Dace, Nase and Barbel are commonly taken besides the bottom-dwelling gobies. In all habitats Cormorants also take prey that are highly valued by Man. In standing freshwater systems these are Pikeperch, Eel and Whitefish (*Coregonus*) species, in coastal waters Herring (*Clupea harengus*), Whitefish and Sole, and in riverine systems Grayling, Trout and Charr species, and Atlantic Salmon.

Although the major proportion of Cormorant diet consists of economically unimportant species, some birds do feed on the less common, commercially important species. Whether this predation leads to any effect on the prey fish is impossible to determine just from the percentage occurrence in the diet. However, it is important to consider two important facts. First, the Cormorant is not necessarily

Productivity in Cormorant colonies varies according to the availability of food. Most clutches contain 3–4 eggs (range 2–6) but the number of young that fledge varies greatly from 0.5–2.7 per nest on average (range 0–4).
Photo courtesy of Florian Möllers.

selecting any particular species of fish while foraging in a particular water body. This implies that, on a large geographical scale, rare and protected fish species are unlikely be threatened by this predator. Second, when relatively large numbers of Cormorants are on migration (or making shorter movements in search for ice-free foraging sites) and visiting small running waters (e.g. in the pre-Alpine region), the fish there may well be temporally vulnerable to predation. The amount of available shelter will determine the fishes' chance of escaping predation and could limit any effect at the population level. Connectivity to other parts of the catchment area is also important with respect to recovery from predation losses. Generally, fish survival is considered to be higher in more natural water systems but the effect of stocking with naïve stock (both particular breeds or individual fish), in combination with modified habitats and water flows due to river management will usually lead to greater predation effects than in natural systems.

The role of artificial water bodies in relation to the predatory effects by Cormorants is similar. As fish here are often no longer able to perform their annual movements, (e.g. from rivers to the deeper parts of lakes, or from lakes to coastal areas) they tend to concentrate at very specific places. This is often the case at weirs, sluices, locks, near dams and other obstacles, often in the deeper water sections. The regulation of water levels that accompanies the hydraulic restructuring of water bodies often means a degradation of densely vegetated natural shores. At fixed water levels and high nutrient loads reedbeds are known to retreat as a result of the erosive mechanical power attacking the stems at the same point (e.g. Ostendorp *et al*. 1995). The man-made lakes used for water storage, for energy supply or recreation, often have artificial (hard stone or concrete) or very steep shores without much vegetation which would serve as shelter. In all these cases, fish tend to be more susceptible to predation by Cormorants although here, too, it is unlikely that their populations are negatively affected by predation in the longer term.

The trend to increase the number of hydropower reservoirs over the past decades has undoubtedly contributed to the wintering site possibilities of Cormorants. This is especially true for Spain, Portugal and Italy, but also for Greece and elsewhere in the Mediterranean where these water bodies are now important foraging waters for Cormorants. Furthermore, the resulting patches of drowned forest often serve as roosting areas for the birds in these waters.

By contrast to the situation in winter, when numbers are dispersed over large areas, the area of available foraging waters in the North Sea-Baltic region and the NW parts of the Black Sea should, at a European level, be considered core areas for Cormorants. Both coastal, lake and larger river deltas and lagoon systems are present at a density that has no parallel elsewhere in Europe. It is in these two 'mega-regions' that Cormorants breed (and part of the population also winters) in large numbers, fully in accordance with their apparent preference for eutrophic (i.e. nutrient-enriched) shallow waters.

Due to predicted global climate change, the climate window that Cormorants operate within will likely tend to move farther northwards. The current shifts in Cormorant distribution associated with this will thus lead ultimately to more available space in summer to breed and, perhaps more important, to winter as well. The present expansion of breeding Cormorants in the Baltic region is certainly in accordance with this scenario. Whether this also holds for southern areas in the Russian Federation is not known. Besides earlier access to, and the availability of, a larger breeding area there is also likely to be an effect of global change in winter. Milder winters will eventually lead to more birds beginning to winter in the same region as they breed, as suggested strongly by current increased numbers in the northernmost range of the current 'traditional' wintering area. Parts of UK, The Netherlands and Belgium, northern Germany and deeper water areas in Denmark, Sweden and Poland will probably thus see increasing Cormorant numbers in winter. This might also be true for the northerly regions in the Balkans, Bulgaria and Romania. The future use of the Mediterranean by Cormorants is also very interesting in this respect. North Africa (the traditional southern fringe of wintering *sinensis* birds) is supposedly not used so much by wintering birds anymore. Whether the overall increase in the Nordic populations of Cormorants will mean an increase in wintering numbers in this area again is difficult to predict, although not unlikely.

13.1.2 Fishes

Large numbers of Cormorants across Europe are known to be associated with eutrophic water bodies. After protective measures were taken in most European countries from the 1970s onwards, enhanced fish production, combined with less clear waters, have provided better feeding conditions for Cormorants. Eutrophication is considered a major driver behind the Cormorant's recovery. The phenomenon of nutrient enrichment is still apparent in large parts of eastern and southern Europe, whereas in western and northern regions there is a reversed pattern of lower nutrients levels due to a strong reduction policy in the 1980s and 1990s. The Cormorants' range expansion into more easterly and southerly regions of Europe has thus been facilitated by two effects: those of a milder climate and of greater fish abundance and availability due to eutrophication. As an example of the large-scale effect of eutrophication in the Baltic Sea, Figure 13.1 shows the extent of algal blooms as visible by satellite, with peak values appearing in a wide belt in the southern Baltic ranging from Öland all the way east to Latvia. The blooms in the shallow waters in western Estonia and the easternmost of the Finnish Gulf near St. Petersburg are obvious. In coastal areas these correspond to those regions where Cormorants spend the summer months, either breeding or in post-fledge aggregations.

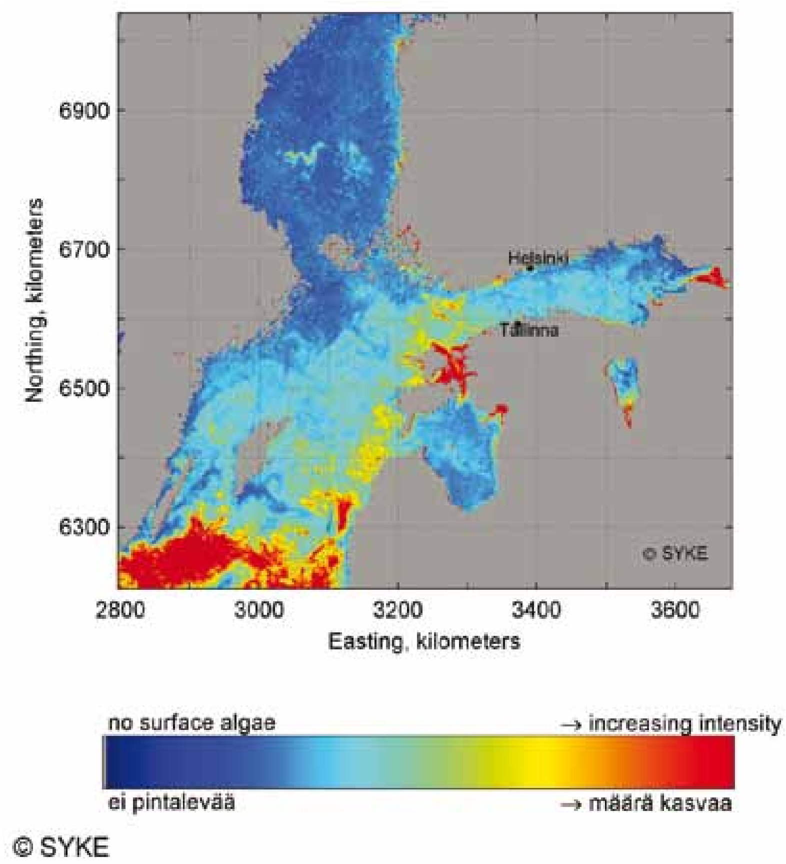

Figure 13.1 Example of algal blooms in the Baltic Sea as depicted by satellite images taken during summer 2006. More blooms occur in southern and shallow water areas. Notice also the apparent bloom in the southern part of Lake Peipsi, and that the southernmost (and most polluted) part (Lake Pskov) has not been included in this picture (Source SYKE, Helsinki).

Human influence is most likely the main reason behind such large-scale ecological changes in the Baltic Sea. The productivity of the Baltic has increased at least two-fold in the last 100 years. This is ultimately apparent in less-clear water, but has had drastic effects on other parts of the ecosystem too. Although large cyanobacteria blooms are a natural phenomenon, their present intensity most certainly is not. Regardless of the reasons for increasing productivity in the Baltic Sea, it is impossible to assess how this additional production is transferred through the food web. There are no proper estimates of the total biomass of top predators (fish, birds and seals) over the past century, but the Baltic Sea is certainly able to sustain a large amount of animal productivity. It is theoretically able to produce even more, and the 'unused' primary production may detrimentally affect the ecosystem. The timing and species composition of seasonal algal blooms is resulting in lower consumption levels of primary production in the food web (see pp. 147–54 of Wahlström *et al*, 1996, SYKE 2006). In combination with higher water temperatures, the increased organic matter content in the water reduces oxygen levels on the seabed, and this promotes blooms of toxic algae. As a consequence, the water becomes more turbid (less clear) and benthic organisms receive less light and suffer from anoxia (that is periods when oxygen content in the water due to consumption by algae during nighttime is near zero), whilst the reduction of benthic filter feeders further increases the production of algal biomass. As a consequence, there is less seaweed and submersed macrophytes and fish populations become simplified. For example, pelagic plankton-feeding fish such as Herring and fish that prey by sight start to disappear from the system. This species shift causes more tolerant prey fish species like Gobies, Butterfish, Eelpout and Cyprinids to increase and, together with turbid water, offers very favourable foraging conditions for Cormorants on a very wide scale.

13.1.3 Human fisheries

Man as commercial fisherman

Besides his effect through eutrophication, Man as a commercial fisherman plays an overriding role in many ecosystems. Through large-scale over-fishing of predatory fish cascading effects result at many lower levels in the food chain. This is a pattern that has been observed in many marine, river and lake ecosystems across the globe, ranging from China, Canada, West Africa and also Europe (see Scheffer *et al*. 2005). Ultimately this process leads to ever smaller prey sizes, a phenomenon known as 'fishing down the foodweb' (Pauly *et al*. 1998). As well as the dominance of smaller-sized fishes, high fishery pressure also results in a reduction in the reproductive age, in other words fish stay smaller and tend to reproduce at a younger age as a result of the intensive fishing. As described elsewhere, an abundance of small fish as a result of over-fishing, is highly attractive to Cormorants.

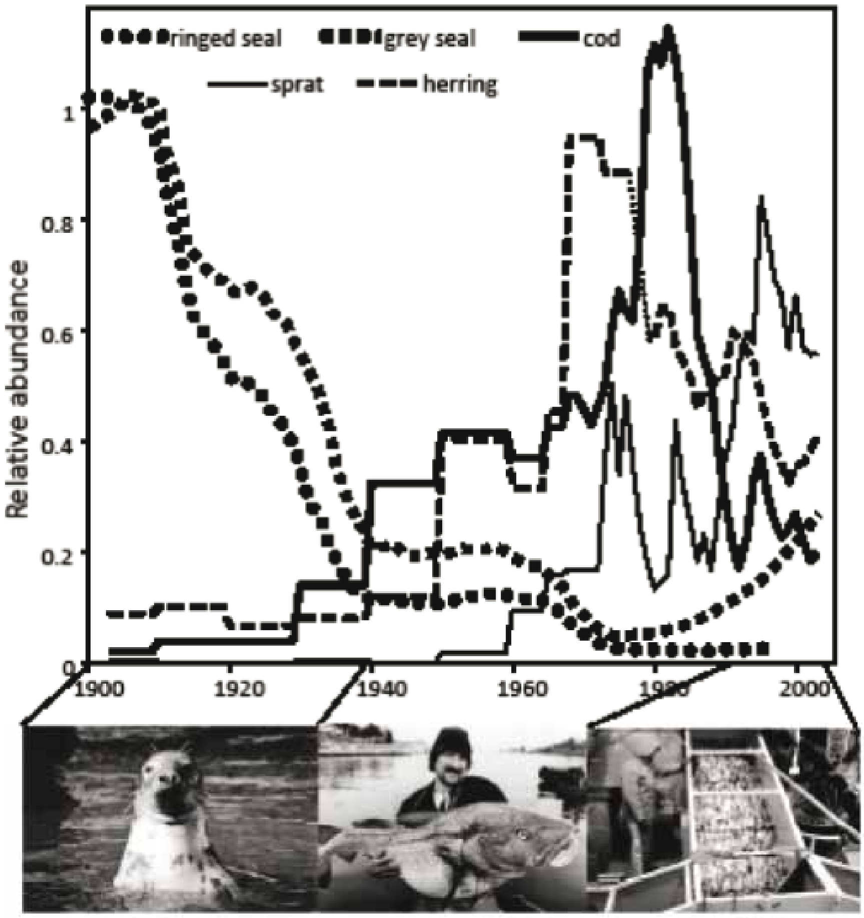

Figure 13.2 Long-term changes in catches and abundance of different key organisms in the Baltic (after Österblom *et al.* 2006) and trophic relationships between cod, sprat and plankton as well as the alternative predators pike and perch (right). The Cormorant's appearance since the mid 1990s runs parallel to that of the reappearance of the Grey Seal.

The next examples are again taken from the Baltic Sea, further demonstrating this area to be an increasingly important one for Cormorants. By comparing Cod (*Gadus morhua*) from the Neolithic period (5300–3900 BC) with Cod from contemporary times, researchers have discovered that the species has evolved over a relatively short period as a result of human overexploitation. According to a recent scientific paper (Limburg *et al.* 2008), contemporary Cod attain adulthood earlier (3.7 years versus 4.7 years) and are generally smaller than their ancestors (49 cm compared to 56 cm). The Baltic was not very rich in fish during the first part of the 20th century and, compared to the present situation, there were many seals (*Phoca vitulina, P. hispida* and *Halichoerus grypus*) and harbour porpoises (*Phocoena phocoena*), regarded as the natural top predators in the system. Because of perceived competition with human fisheries, these mammals were heavily persecuted during the first half of the 20th century (see Figures 13.2 and 13.3). This and the effect of eutrophication allowed higher productivity levels, which (after World War II when fishing effort was relatively low) resulted in large stocks of both Herring and Cod, the cod now being the new top predator in the system.

Catches of Herring increased sharply to peak levels in the 1970s, followed by large catches of Cod during the 1980s. Both species decreased as a result of this heavy fishing pressure, and then another pelagic fish, the sprat (*Sprattus sprattus*), began to increase in the 1990s. This species is a food competitor of the Herring and, although of less economic importance than it, became heavily exploited too as a result of the declining stocks of Herring and Cod. Although not monitored specifically, the disappearance of the Cod is likely to have had an effect on the near-benthic fish community now released from predation by Cod. The appearance of large numbers of Cormorants seems logical in this set of cascading events. As a predator of both the near-benthic fish community and of the more pelagic schooling fish species it may likewise have profited from the disappearance of Cod from the Baltic system.

This type of example is not restricted to the Baltic. In many fished ecosystems, that is to say in nearly all large-scale waters, there are indications that the large predatory fish species have been over-fished, very often resulting in conditions that are highly favourable to Cormorants.

Over-fishing during the 1980s thus contributed to a decrease in the Cod stock, which has led to a number of effects on other components of the Baltic Sea food web — it is becoming increasingly clear that Cod play an important part in the dynamics of this ecosystem.

Cod is the most valuable species for fisheries and the size of the stock has a large impact on the economy for commercial fishermen. Despite the advice from ICES, that a substantially decreased Cod fisheries could lead to improved long-term potential for catching more fish, politicians have not yet had the courage to take the necessary decisions (see Figure 13.4). Preliminary calculations indicate that a few years of dramatically reduced fishing could lead to a rapid increase of the Cod stock in this area (Hjerne & Hansson 2001). From our results and synthesis outlined above we predict that the return of Cod would mean that Cormorants are faced with a less superfluous (small) fish supply and that this might result in a drastic decline in their population.

Man as fish farmer

Fish farms are artificially managed water systems which tend to act

Very probable relationships

When the Cod stocks decreases the stock of Sprat grows stronger and bigger and this leads to a decrease of zooplankton.

Probable relationships

The decrease of Cod can also lead to a decrease of Perch and Pike because they have to compete with the stock of Sprat that has grown stronger and consumes a lot of food (zooplankton).

Interesting hypotheses

When the Cod stocks decrease, the stock of Sprat grows stronger and bigger and this leads to a decrease in zooplankton. This could lead to an increase of phytoplankton which leads to muddy and hypoxic water.

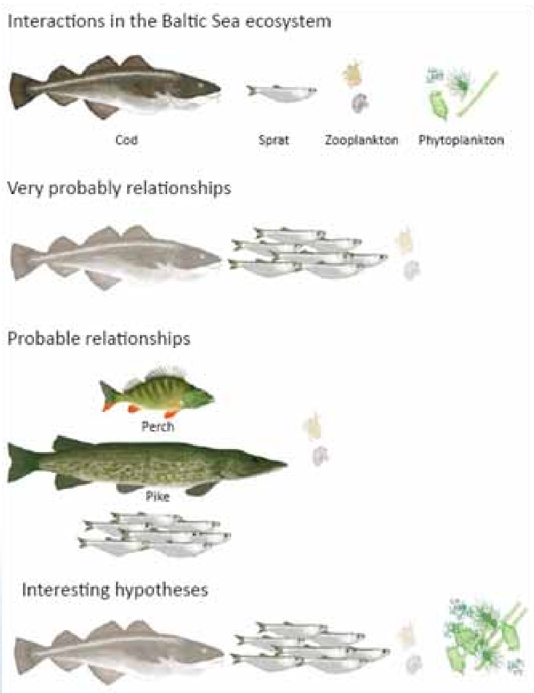

Figure 13.3 Relationships between Cod and other trophic levels in the Baltic Sea. (From Österblom 2009). The abundance of small fish (here Sprat) in all routes is providing favourable food conditions for Cormorants.

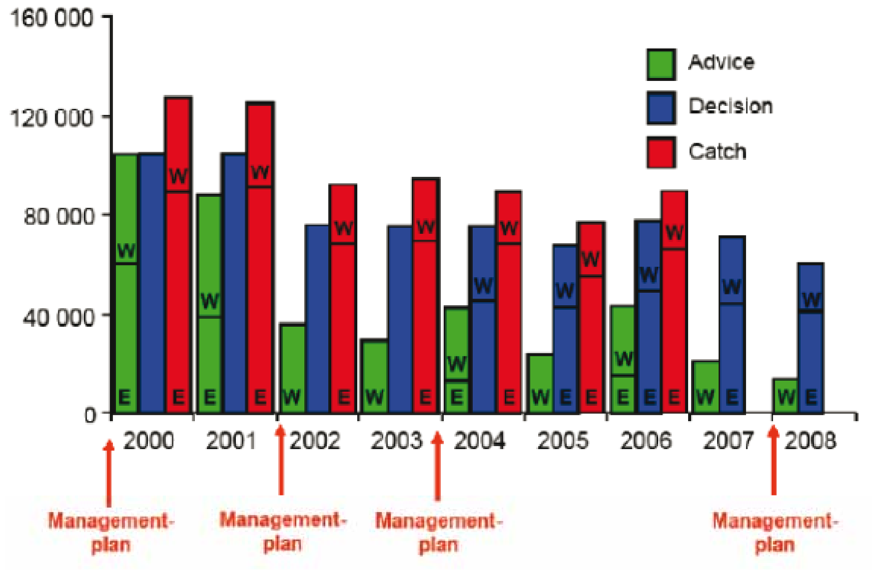

Figure 13.4 Over-fishing of Cod in the Baltic in recent times. After the strong decline in catches the 1980s, ICES advice on catches (green bars) has been consistently lower than the politically achieved decision on allowable catches (blue bars), whilst actual catches have been higher still (red bars).

as 'honey pots' to Cormorants by offering high densities of relatively small fish (very often Carp) kept in shallow water. Fish density is almost always higher in these systems than it is in nearby natural waters (up to a factor of 10 and even up to 100 times greater) and water depth is usually less than 1.5 m in most cases. Fish farms can be used by Cormorants if a breeding colony is nearby but because most fish farms tend to occur in regions without much other open water, the number of breeding Cormorants in the neighbourhood of fish farms tends to be relatively low. More often, Cormorants visit fish farms in late summer and autumn when the birds are on migration. In many places, Cormorants also frequently visit fish farm areas during the winter, especially if the fish farm area consists of many ponds and/or if larger lake or river systems are nearby. The way farm pond systems are used has developed over time. For example, though less intensive than during GDR times, Carp production in Saxony is still intensive and there are local problems with water quality, including algae, the disappearance of macrophytes, low oxygen content and increased turbidity. Similar intensive production conditions occur in the larger pond complexes in France, the Czech Republic and Poland. When Carp are grown for the consumption market, fish farmers generally put the one-year and two-year-old age classes to grow in larger ponds at higher densities. The 0+ (young-of-the-year) fish are generally kept over winter in tanks or small ponds covered with nets. In less intensive situations like those in Brenne in France, fish are grown over several years. Here, the ponds usually have more aquatic vegetation than do other systems and fish densities are generally lower as there is no artificial feeding. On the other hand, extreme densities of over 10,000 kg per hectare of Carp occur in some fishponds in Israel. The more fish in the pond, the more susceptible the system is to foraging predators such as Cormorants. The actual predation of fish is not the only problem; also the mere presence of foraging birds and the associated disturbance can cause additional mortality to fish because of the stress it induces.

Man as sports fisherman

Historically, angling was purely the exploitation of wild fish stocks, but for decades anglers have intensively managed their stocks to enhance their sport. As water quality has declined and hydrological 'improvements' to sections of river have become common practice, the demand for active management has become stronger. The stocking of fish from other water bodies, the introduction of non-native species, the release of naïve 'fingerlings' (i.e. juvenile fish) to restore stocks are all commonly applied techniques to increase catches and to make waters more attractive for recreational angling. Like fish farms, stocked angling ponds and river sections become more vulnerable to predation as densities of fish, relative to adjacent habitats, increase. The use of hand-reared fish stock further increases the risk of considerable loss to predation. This is due to the fact that fish reared in captivity show little or no fear of predators. As in fish farms, most Cormorant predation at angling waters occurs during migration periods and also in winter. During these periods, birds very frequently switch feeding location and look for alternative foraging sites and this is when these systems are most commonly visited. Thus in pre-

Alpine streams, Cormorants may concentrate during periods of frost, as a consequence of the freezing of their preferred lowland habitat. The effects of Cormorant predation on fish stocks are generally found to be lower in cases where (1) river systems are connected (i.e. they are more open systems allowing fish to move freely and to repopulate depleted areas), and (2) habitats are relatively complex and offer good cover/refuge for fish, often the deeper sections of rivers with natural shelter in the form of things like boulders and woody debris or in ponds and small lakes with a strong natural growth of macrophytes and natural shore vegetation.

13.2 Epilogue: towards a solution of 'the Cormorant problem' from an ecological perspective?

Concerted management activities to reduce Cormorant numbers overall have not yet been carried out across Europe, but are continually demanded by some fisheries sectors as the solution to Europe's Cormorant problem. Such coordinated management between countries and involving the likely culling of many thousands of Cormorants each year is certainly, on ecological grounds, considered inadequate to resolve the problem. This is because it does not recognise any of the causal relationships which underly the present European Cormorant situation. With any large-scale culling or shooting activities directed towards the reduction of the total European Cormorant population, the birds would be treated as a kind of pest species. Not withstanding the costs of such an enterprise (which have never been quantified), population modelling has shown that such a strategy would only have limited effect. Given that the potential prey base for European Cormorants in natural waters remains 'super abundant' (as is the case for the majority of waters in Europe), the plasticity of the Cormorant population is such that measures to reduce it will very soon be compensated for by increased birth rates, higher survival and/or immigration into the 'population' being managed. This section explores and synthesizes possible solutions to the Cormorant conflict from an ecological perspective.

Changing worlds but persistent habits

European legislation and the local protection of a species that has expanded widely in the eastern part of its European breeding range has caused a significant increase in the number of Cormorants. Landscape restoration activities, as well as integrated protection schemes such as those under Natura 2000, have also greatly improved the environment for Cormorants. In the near future this situation will continue and lead to larger populations of Cormorants, related for example to the poor environmental state of the Baltic. Along the coastal areas of the Baltic States, in Sweden, Poland and locally in some states in Germany (Mecklenburg-Vorpommern) for example, Cormorant numbers are likely to increase further. These higher numbers of birds will be increasingly often observed in the Balkan countries in winter, but will also lead to higher use of local water bodies in the region of the North Sea and Baltic, if the current pattern of milder winters continues. There is thus no reason to believe that there will be a shift towards reduced Cormorant predation pressure on many of Europe's fisheries in the near future at least.

Some stakeholder groups argue strongly that Cormorants are the single most important cause of the economic losses experienced by many fisheries, regardless of whether these be commercial fisheries, fish ponds, or recreational angling waters. However, as discussed elsewhere, the situation with respect to these different fisheries activities is neither constant nor always sustainable from economic and/or social points' perspectives (see Part Three of Marzano & Carss, 2012).

For example, the economic story of a decline in the prospects of the Carp market became very evident during **INTERCAFE's** work. Customer demand for other fish species has redirected the market, and changing international trade relationships have created a different perspective for the traditional producers. From the ecological perspective, Carp ponds can be seen as 'honey pots' on the birds' flyways to and from the main foraging areas. Protection of these pond areas of special interest is easier if wetlands of sufficient surface area are available to the birds as alternative foraging sites when disturbance actions are undertaken.

Today, many commercial fisheries face the prospect of over-fishing and, associated with this, ever stronger regulation in the form of catch quotas. The new EU Member States are still in a position of transition from the original State-directed system towards a more free-market one, with all its many social and economic problems. Given this socio-economic transition, often associated with a lot of tension for the individual stakeholders, the confrontation with a relatively recent arriving natural predator as the Cormorant accellerates the tension (Carss *et al*. 2003, Carss & Marzano 2009, see also Marzano & Carss 2012).

Like angling, bird watching is an outdoor activity which is an increasingly popular form of recreation. Especially in the more densely populated parts in Europe wetlands are visited by increasing numbers of people and Cormorant colonies or roosts are among the sites offering guided excursions (e.g. in The Netherlands, Denmark) or the opportunities of more informal visits visiting bird hides (e.g. in The Netherlands, France, Belgium, Germany, Denmark, Sweden, Poland). These activities are also becoming an increasingly important part of local economies through the associated transport, accommodation and specialized equipment sectors. Interestingly, this trend is more apparent in densely populated areas than it is in rural ones in Europe where traditional land-use patterns like fish-farming still prevail.

As the European Cormorant population links all these very different social and economic worlds, it is clear that no single solution to the conflict is ever likely to be successful, given the fact that the perception of the problem differs across Member States.

The conflict in the ecological perspective of the triptych

The ecological conditions that Cormorants face today appear to be very favourable for the species' good population status. The banning of pesticides, a Europe-wide amelioration of water quality and protective status has all had their effect. However, the changes in the hydrographical conditions of many rivers and lakes that have been undertaken over the same time frame have led to conditions where fish populations have limited migratory space compared to earlier conditions. This has had negative consequences for the spawning of fish and has ultimately lead to simplified ecosystems where fewer fish species are present. As described above, these less natural conditions also offer higher chances of predation by Cormorants. The eutrophic status that persists locally for many water bodies enforces this effect and, combined with a heavy pressure from fisheries activities, has lead to a further shift in species composition towards the increase of commercially non-important species (e.g. Ruffe *Gymnocephalus cernuus* as a result of over-fished stocks of Pikeperch in IJsselmeer) or Sprat and Eelpout *Zoarces viviparus* as result of diminishing Cod stocks in the Baltic).

'Fishing down the food chain' leads to the abundance of smaller fish species and a shift in size classes, from larger species towards a preponderance of smaller species and/or individuals. Finally, the introduction of non-native species for use in angling waters has contributed to unfavourable conditions for many native species. All these changes lead to a situation in which the large fish predators (or, still earlier, mammalian predators like small whales, dolphins, and otters) are being 'replaced' in food webs by avian predators, in this case the Cormorant. The greater ability of this species to move over large distances, coupled with higher reproduction rates, allows these birds to feed and breed over wide geographic areas. High Cormorant numbers are thus an ecological sign of the super-abundance of small fish prey, a situation which under natural conditions prevails in estuaries, lagoons or shallow

Commercial fisheries have a great impact on fish composition in many European waters (species and size distribution shifting towards smaller individuals). Moreover, discards of fish form an attractive prey for many fish-eating birds including Cormorants, Lake Markermeer, The Netherlands. Photo courtesy of Florian Möllers.

coastal zones and large river sections, but is also the result of disturbed aquatic ecosystems.

The suggestion from all this is that Cormorants may be good indicators for the environmental state of a water systems, rather than the ultimate cause of the ecological disturbance to it. Ecological monitoring of the species (especially numbers, food, status and distribution) may thus provide valuable information and indicate any changes in water quality and effects of fisheries management programmes. Managing basic resources in an ecologically sustainable way would seem a far more viable option than to adopt large-scale management of the predators themselves.

A regional approach for solving local problems: the European Watershed Hypothesis as example

This work has shown clearly the complexity of the ecological relationships associated with Cormorants feeding on fish. As ecological conditions and management in different parts of the species' range vary considerably, there is little chance of a single pan-European solution that can cope with all these differences. Cormorants react to differences in food abundance and, because of their ability to fly large distances; they are perhaps better able than other predators to detect areas where fish are abundant, either naturally or as a result of Man's actions (i.e. management of wild stocks or commercial/recreational enterprises). Spanning the complete range of marine to freshwater and from large-scale coastal waters to isolated ponds, Cormorants operate at a 'global' scale across Europe and beyond. Their geographical range encompasses a vast diversity of human social, cultural and economic systems. The social and economic backgrounds associated with people's perceptions of what is important and acceptable or not in relation to Cormorant-fisheries interests is dealt with extensively in Marzano & Carss (2012). Here we confine the discussion to an ecological perspective on the conflict where it is clear that for large-scale open water bodies the problems with Cormorants are mainly related to the improper management of wild fish populations by Man. Devising sustainable fisheries for the predatory fish species seems the most effective way to shift these systems into more balanced situations. This needs coordinated action and will, of course, not be simple. The result, however, will have important consequences on the European population of Cormorants and for the systems themselves. As most Cormorants in Europe rely on these larger-scaled water bodies, consistently applying the principle of 'wise use' will initially slow down the population increase and subsequently turn it back to lower levels. This will be the ultimate task if one is to control Cormorant numbers. As a result of lower overall Cormorant numbers, fewer cases of conflict will also arise on those river sections, lakes and small streams which do not have unnaturally high concentrations of fish. Natural management, aimed towards variable habitat structure and natural water level fluctuations will allow fish to migrate, spawn and hide from predators. Clearly, at both ends of the geographical scale, management of basic resources is thus considered vital for any solution of the current Cormorant problems.

For the short term at least, two types of conflict cases remain, both associated with smaller-scale water bodies. The first and geographically most widely distributed group of cases is that of fish farms (see also Seiche *et al.* 2012), the other related to small upland and mountain rivers. Larger numbers of Cormorants, often migrating or moving to and from their core habitat (focused on large-scale water bodies) can cause problems with local fisheries. From this investigation, the area of most intense reporting of conflicts seems to coincide more or less with that part of Europe where large-scale waters are scarce. At a continental level this may be seen as the 'European Watershed', dividing the coastal Baltic/North Sea/Atlantic river catchments from the Black Sea/Mediterranean. Since historical times, people have tried to manage their local fish supply by creating fish ponds and using small streams as a local source of water. On their way to their wintering areas, Cormorants pass these watershed areas with a relatively limited area of foraging waters and may eventually be present there in large numbers.

Can we use this 'European Watershed Risk Hypothesis' for the alleviation of local problems? It may well be possible if detailed knowledge of timing of bird migration is linked to a temporal recording of the development of weather patterns. Cold weather arriving from the north and tailwinds favouring bird migration are known as important triggers for bird migration (Alerstam 1981). As such, a GIS based warning system could be developed which may direct the incidence of disturbance actions to be taken against Cormorants. Applying disturbance at a site before commonly used by the arriving birds during autumn and spring migration is probably the most effective way to avoid settlement of larger groups in a 'new' area. The same probably holds for the pre-Alpine lakes and streams at times of frost when nearby still waters at lower altitude freeze over. Based on GIS information, the combination of the water charts and the occurrence of sensitive streams and fish-farm areas could be used to arrive at an integrated 'early warning' system. Such an early warning system system based on on-the-spot information has been shown to work at a regional scale in Israel where it was successfully applied in case of managing conflicts in populations of Crane *Grus grus* and White Pelican *Pelecanus onocrotalus*. This approach would combine detailed geographical information and the availability of resources, knowledge of bird migration habits and may direct local managers to effectively carry out protective measures. When carried out in such a sophisticated way, the measures are likely to be far more effective because they are coordinated and timely reactions to the birds' movements and specific needs. The work presented here has paved the way to such an approach, setting up the GIS framework and bringing together most of the biological data that are needed to model Cormorant movements/ migration in relation to available resources and such things as weather and climate.

Recommendations in short

From the ecological point of view, the main conclusions of this work can be summarized and several recommendations offered which are considered crucial to the resolution of European Cormorant-fisheries problems:

- Reduction of the continuous over-fishing by man of stocks of large predatory fish species at sea and in large lakes, by promoting the sustainable use of fish resources.
- Reduction of extensive nutrient loads that currently still affect water systems, causing algal blooms and leading to simplified fish communities.
- Removal of barriers in rivers and lakes, thus restoring the aquatic connections used by fish.
- Stimulating and restoring more natural conditions in smaller still waters, avoiding intensive management with continuous stocking of non-autochthonous fish species.
- Restoring habitat quality in aquatic systems by favouring the development of natural shores, allowing for naturally fluctuating water levels wherever possible and promoting emergent and submerged vegetation used by fish to spawn, grow, and shelter from predators.
- Stimulating the communication of information between different stakeholder groups, the exchange of common practice to develop the sustainable use of complete ecosystems which including Cormorants and other natural top-predators.
- Developing an 'early warning system' of migratory Cormorants in risk-sensitive areas (the so-called EU watershed area).
- Increasing the protection of sensitive fish species and sites by netting, acoustic or other measures (see Russell *et al.* 2012).
- Adapting fish stock management in the most vulnerable areas by rearing larger-sized fish less prone to predation in recreational and commercial fisheries.
- On the spot disturbance or shooting of Cormorants at the most vulnerable sites when other measures fail, in combination with the provision of 'buffer' areas where the species is allowed to forage unmolested.