4 Cormorant ecology: factors leading to conflicts

4.1 *Introduction and methods*

Any successful resolution, or management, of the conflicts between Cormorants and fisheries interests on a pan-European scale must include careful consideration of the best available biological information on Cormorant populations throughout the region. This Work package was an attempt to synthesise aspects of Cormorant ecology that lead to the conflicts synthesised in Chapter 3. The conflict synthesis highlighted that Cormorants were widespread across Europe, that they were migratory (at least in part) and that they were highly flexible in relation to choice of foraging habitats and prey.

The aims of this Work Package were thus to (i) achieve information exchange at a European level (ii) summarise existing knowledge on Cormorant ecology (especially factors leading to conflicts), (iii) clarify certain ecological topics (focussing on feeding ecology), and (iv) synthesise common facts in a general synthesis giving a broad, pan-European overview.

Relevant ecological factors included in the synthesis were: Cormorant population status and distribution, movements and dispersal, breeding/over-winter site fidelity, foraging site selection, foraging ecology, feeding behaviour and daily energy expenditure. These factors were categorised into four main themes:

- General ecology and habitat features
- Migration and the annual cycle
- Fish communities and Cormorant diet
- Cormorant ecology and impact at fisheries

These main themes were discussed in a series of topical reviews presented by a REDCAFE participant and the main points arising from each are summarised in this Chapter (sections 4.3, 4.5, 4.6, 4.7). In addition, wherever appropriate, subsequent discussions between REDCAFE participants are also reported. Two discussion workshops were also held to discuss and synthesise broad habitat issues: the environmental requirements of Cormorants and habitat 'vulnerability' (i.e. its attractiveness) to the species. The resulting consensus on these habitat syntheses (presented in sections 4.4, 4.8) are reported here in the form of tables. A pan-European synthesis is then given (4.9) along with three sets of conclusions arising from it (4.10).

Finally, the pan-European synthesis was achieved by incorporating information from the topical reviews and discussion workshops and combining it with information on the inter-relationship between Cormorant density and distribution across Europe based on site-specific information reported by REDCAFE participants in a standard format (Table 4.1)

README: Please submit data of your country in the yellow space of the area sheets.
If you wish to contribute data on more than one area, you can use the next 10 area sheets.
Explanation of habitat type:

1. Open Sea
2. Estuaries
3. Inland sea
4. Large lakes
5. Large rivers
6. Impounded rivers
7. Streams / small rivers
8. Reservoirs / small lakes / sandpits
9. Fish ponds
10. Brackish lagoons (on request of Italy)
11. Fishing valli (on request of Italy)

* please choose option in area form

SHEET: In the Excel datasheets one more column was added to input the data. Ten of these sheets were included in the mailing to allow data input on 10 different sites. Furthermore, we asked for the name of the respondent, country and the name of the site. We asked data on the following data Blocks:

Time of study, geographical position and type of habitat data:	
Issue	Specification
HABITAT-TYPE	see README
LOCATION	Greenwich coordinates
REFERENCE(S) OF STUDY	peer / non-peer reviewed / anecdotal*
PERIOD OF STUDY (give range)	year(s)

Population data:	
Issue	Specification
SUB-SPECIES	carbo / sinensis*
NUMBER OF CORMORANTS INVOLVED	Maximum
NUMBER OF CORMORANTS INVOLVED	birddays per year
STATUS OF CORMORANTS	breeding / non-breeding*
FLOCK SIZE AT TIMES OF FISHING	average number of Cormorants
OCCURRENCE OF MASS FISHING	yes / no*
JUVENILES	% of number

Water body characteristics:	
Issue	Specification
SIZE OF FISHING WATER	Km^2
WATERBODY	natural / semi-natural / artificial*
DEPTH	M
TROPHIC STATUS	oligotrophic / mesotrophic / eutrophic*
TURBIDITY (SECCHI DEPTH)	M

Fish data:	
Issue	Specification
FISH SPECIES IN AREA	Number
FISH SPECIES / GROUP MOST ABUNDANT (rank 1)	latin name
FISH SPECIES / GROUP MOST ABUNDANT (rank 2)	latin name
FISH SPECIES / GROUP MOST ABUNDANT (rank 3)	latin name
OVERALL FISH BIOMASS	Kg/ha
DENSITY OF MOST ABUNDANT SPECIES (rank 1)	Kg/ha
DENSITY OF MOST ABUNDANT SPECIES (rank 2)	Kg/ha
DENSITY OF MOST ABUNDANT SPECIES (rank 3)	Kg/ha
FISH SPECIES IN DIET	Number
FISH SPECIES / GROUP EATEN MOST (rank 1)	latin name
FISH SPECIES / GROUP EATEN MOST (rank 2)	latin name
FISH SPECIES / GROUP EATEN MOST (rank 3)	latin name
DENSITY OF MOST EATEN SPECIES (rank 1)	Kg/ha
DENSITY OF MOST EATEN SPECIES (rank 2)	Kg/ha
DENSITY OF MOST EATEN SPECIES (rank 3)	Kg/ha
OVERALL CONSUMPTION	% taken from available (Kg/ha)

Fish data:	
Issue	Specification
(all fish species)	
CONSUMPTION OF MOST EATEN SPECIES (1-3)	% taken from available (Kg/ha)

(Inter)colony data:	
Issue	Specification
DISTANCE OF COLONY OR ROOST TO FISHING WATER	Km
DISTANCE TO NEAREST COLONY OR ROOST	Km
DISTANCE TO NEAREST ALTERNATIVE FISHING WATER(S)	Km
COLONY / ROOST EXISTENCE	number of years
COLONY / ROOST HABITAT	willow / poplar
	alder / birch
	ash / oak / beech / birch / lime
	coniferous
	ground nesting
	other
POPULATION INCREASE OR DECREASE	% average last 5 years (- = decrease, + = increase)

Table 4.1 Standardised spreadsheet used by REDCAFE participants for collation of Work Package 2 case study information on relevant aspects of Cormorant ecology.

4.2 Ecological framework

In Europe, the population of Cormorants *Phalacrocorax carbo sinensis* has shown a strong increase (Figure 4.1). For example, in 1985 in the core area of western Europe, i.e. the Netherlands, Germany, Denmark, Poland and Sweden there were 29,000 pairs, in 1990 there were 63,000 pairs and in 2000 approximately 125,000 pairs.

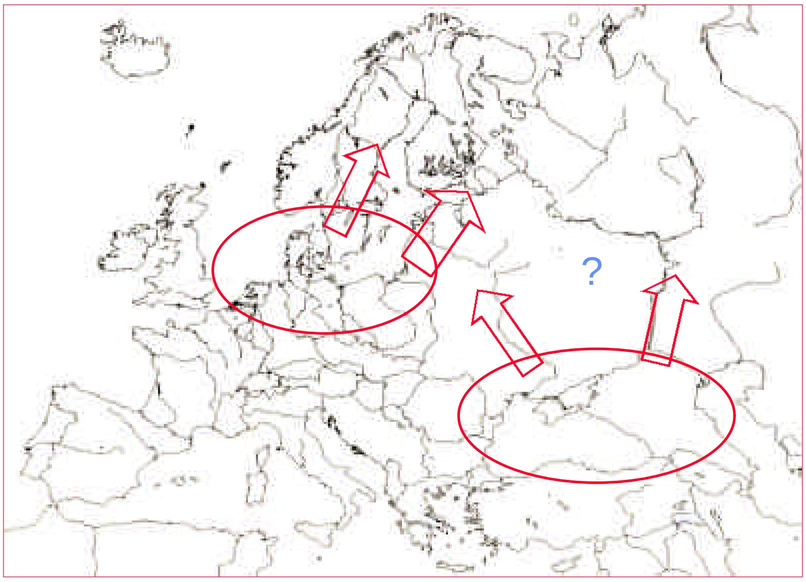

Figure 4.1 Core areas of Cormorant (*sinensis*) distribution in Europe with current direction of expansion (arrows).

In Europe, about 240 fish species are known. In fresh water systems about 24 fish species play a role as food for Cormorants (but see Table 3.5). Of these, about 12 fish species (see Table 3.5 for scientific names) are known to be of commercial interest in at least some of the Cormorant's range: Eel, Carp, Whitefish, Rainbow Trout, Grayling, Perch, Tench, Pike, Perch, Roach and Pikeperch. In salt water systems about 15 fish species are of importance for Cormorants and about 7 of them are of commercial interest: Eel, Cod, Sea Bass, Dab, Flounder, Gilthead and Mullets.

One of the main questions concerning Cormorants as a potential 'problem' for commercial fisheries is whether or not the species can be seen as an opportunistic generalist predator. Changes in the number of predators in response to the numbers of prey is termed a 'numerical' response. There may also be changes in the number of prey eaten per predator as a result of variation in prey density: this is termed the 'functional' response. Considering predator-prey interactions within the functional response framework leads on to predictions that several factors besides densities of predators and prey are important. Predators may be 'specialists', consuming a single, or small number of prey types, or 'generalists' feeding on a wide variety of prey. Generalist predators may show a weak numerical response to changes in density of a particular prey (see information in 4.9.3), compared with a specialist, preying almost exclusively on that prey. From the information above, and that presented in Chapter 3 (see section 3.3.4), it is clear that Cormorants are opportunistic generalist fish predators. As a result of their broad ecological requirements (see this Chapter), Cormorants do therefore have the potential for considerable conflicts at specific fisheries. This is because, as well as flexibility in feeding site choice, generalist predators like the Cormorant could have considerable impact on their preferred prey species because their numbers are buffered to some extent against declines in these prey by their ability to switch to other types.

4.3 Cormorant ecology and physiology

4.3.1 General Cormorant ecology and habitat features

A generalised abstraction of the complex world of Cormorant ecology should be used to deal with the Pan-European scale required in the present REDCAFE synthesis. The major ecological factors that influence the foraging behaviour of Cormorants were reviewed and grouped into factors acting on their behaviour either directly or indirectly.

Direct factors: Geographical orientation, use of ecotopes , weather (e.g. wind direction, wind force, temperature), water transparency (i.e. min. 40 cm Secchi disk, see Figure 4.2), prey morphology and size of individual fish (commonly 6 - 30 cm), fish body shape (e.g. fins not too pointy) and local fish biomass.

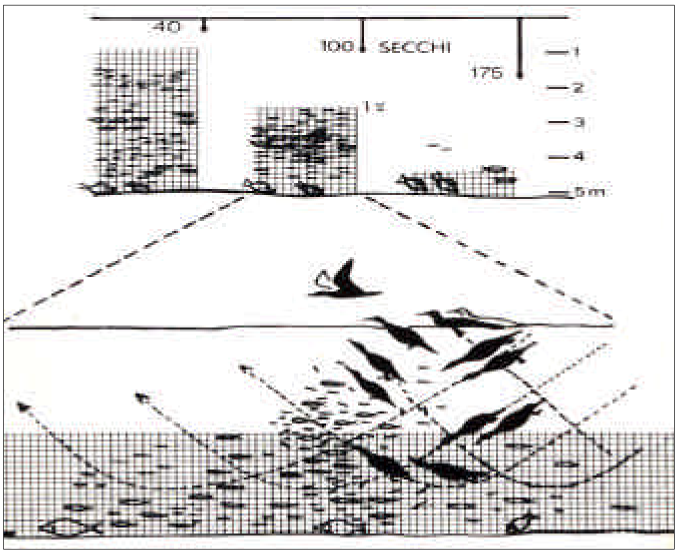

Figure 4.2 Cormorants foraging socially in intermediate turbid waters, pushing fish up towards the clear part of the water column.

Indirect factors: Availability of night roosts or colony locations (including disturbance, predation risk, availability of nest material). Fish ecology (e.g. spawning period), fish migration (horizontal and vertical), shoaling, distance of foraging grounds to night roosts or colonies (optimally < 20 km). Inter-colony competition, mass fishing and status (breeding, migrating or wintering). Most interactions of two or several of these factors have been described in the existing literature on the Cormorant. However, we found no record of integrating all the above factors in a site-specific geographical context on a Pan-European scale. *Mennobart van Eerden*.

REDCAFE discussions: comments in the discussions of published knowledge pointed to a lack of understanding about the influence of (individual) fish behaviour on Cormorant behaviour.

4.3.2 Cormorant ecology: general features

The general ecology of the Cormorant can be described through general dispersion patterns, habitat characteristics, foraging behaviour and roosting behaviour. Cormorants breed and roosts in trees, reed beds and on bare soil or rock. Colonies can, given certain conditions, sustain up to 10,000 pairs and roosts up to 12,000 individuals. Most colonies settle close to foraging waters. Colonies and roosts are spaced out according to hinterland (usually associated with waters of less than 20 m depth: see also 4.4). Colonies and roosts are social assemblies where sex and age classes are unevenly distributed.

In Europe, one core Cormorant area includes the Netherlands, Denmark, Germany and Poland. From this core area Cormorants have expanded into Baltic countries, Sweden and less into central Europe and Great Britain. A second core area exists in Romania, Ukraine and southern Russia. The Cormorant is a migratory species that winters in the Mediterranean and the Back Sea but also at northerly latitudes.

Active fishing by Cormorants occurs during daylight and shows a bimodal pattern often associated with early mornings and later in the day. Birds usually dive to depths of 2-6 m, up to 40 m exceptionally. Most fishing takes place individually or in small flocks. Mass fishing occurs in moderately turbid waters with a flat bottom, both in summer and winter. Diving in cold water raises energy expenditure and thus food requirements. Adults feed their young for 50 - 70 days. Cormorants show individual, age and sex-based differences. The Cormorant is a highly adaptive species and uses a great variety of waters and ecotopes to breed and roost. The social habit of colonial breeding and roosting makes it respond effectively to changes in the environment. We are extremely well informed about distribution and population changes, though less well about the exact causes. Data on East European *sinensis* and Atlantic *carbo* are necessary for understanding the West European *sinensis*, which, according to REDCAFE synthesis (see Chapter 3), causes most conflicts. *Mennobart van Eerden*.

REDCAFE discussions: comments in the discussion focused on the occurrence of mass fishing by Cormorants in relation to turbidity, salinity and bottom characteristics of water bodies. Given dense fish stocks, this type of foraging behaviour occurs over flat bottoms in open areas without any structures like water plants or stones.

4.3.3 Bio-energetic bottlenecks for Cormorants

Some basic questions in relation to the foraging behaviour of the Cormorant are: Do Cormorants have abnormally high energetic requirements ? Can we explain differences in this fish consumption ? Can we predict the distribution of Great Cormorants and their impact on prey stocks? These questions relate to the general impression by fishermen that Cormorants have exceptional skills to catch fish prey. It was found by scientific methods that food intake (300-1000 g/bird/day) is less than that of other seabirds (Figure 4.3). A study estimating the Daily Energy Expenditure (DEE) of wintering Cormorants using the doubly-labelled water technique also found Cormorant DEE to be within the range of other seabirds of similar body mass. Methods used to measure food intake were automatic weighing, stomach temperature records and time energy budgets (Figure 4.3).

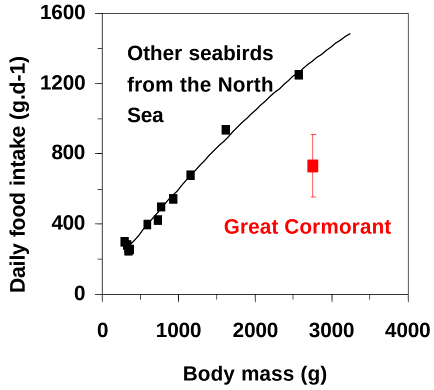

Figure 4.3 Measuring Cormorant food intake (left: comaprison of Cormorant food intake with that of other seabirds; right: breeding Shag *Phalacrocorax aristotelis* on a nest balance).

The partly wettable plumage of the Cormorant may be a morphological adaptation to optimise diving (allowing reduction of buoyancy). However, diving costs in cold water are relatively high due to the wettable plumage. The thermo-conductance adaptation to a cold environment seems to be partly physiological and behavioural. Along with an increase in energy consumption, body temperature rises and foraging efficiency is increased. Less deep dives are made and time in the water is minimised, the catch per unit time increases to the highest recorded in birds. In this way the birds seem to cope with the hostile environment. It was concluded that Cormorants forage close to optimal by adapting their behaviour. *David Grémillet*

REDCAFE discussions: comments in discussion were restricted to remarks on the importance of high quality data loggers and materials to do this kind of research.

4.3.4 The Cormorant's eye: limits to prey detection

Fundamental research into the biology and physics of the Cormorant's eye is necessary to understand the underwater vision of Cormorants. The refractive power of the cornea has been studied together with the eye's capacities of underwater accommodation. While the eye is accommodating, the lens changes shape (see Figure 4.4 for Merganser *Mergus* spp.).

This physiological knowledge is necessary to understand the role of vision in prey detection. Y-maze underwater prey selection experiments in the laboratory with dead prey (fish) show the limits of the Cormorant in detecting prey under different turbidity conditions. On the basis of MAR (minimal angle of resolution) the underwater vision of the Cormorant is better than that of humans but not as good as that of most fish. It is, however, better than that of most marine mammals. Cormorants could have the ability to distinguish between various polarisations of light. This may be relevant when Cormorants are foraging as fish scales polarize light. The existence of mechanoreceptors in fish detection is not confirmed, nor denied. Furthermore, light diffraction depends on many factors among which light polarisation by fish scales is only one.

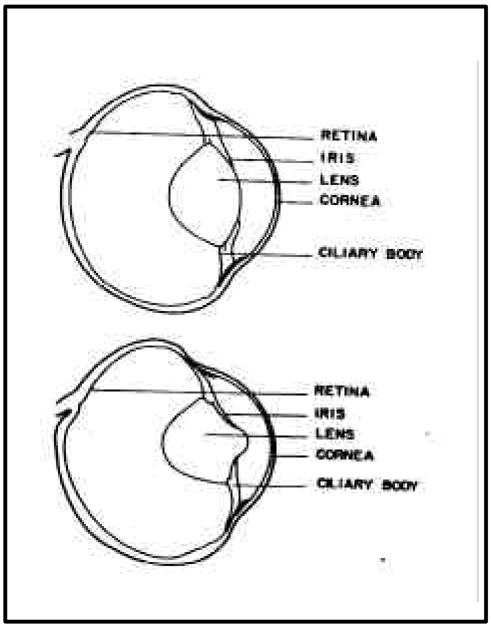

Figure 4.4 Merganser eye, at rest (top) and accommodating (bottom).

In order to understand the role of vision in prey detection, the effects of prey size and distance mı The underwater light climate thus influences the bird's acuity to detect prey. How light intensity, algal biomass, suspended matter interact is only partly understood. Nevertheless, the fact that Cormorants' feed intensively in large numbers in both the IJsselmeer and Sea of Galilee in relation to conditions of turbidity probably has a basis in this prey detection theorem. *Gadi Katzir*.

4.4 The Cormorant's broad environmental requirements

REDCAFE participants considered the 'factors affecting the appearance or disappearance of Cormorants, apart for foraging waters, roosts and breeding colonies' (Table 4.2).

Cormorant roosts can be divided into day roosts and night roosts. Both types of roosts require:

1. Suitable habitat: *sinensis* trees with suitable access (branch structure), *carbo* mostly rocks (although there are now many tree-nesting carbo in S.E. England). Other roosts can be found on sand flats, dikes, or artificial structures like weirs, high tension pylons etc.

2. Protection from human disturbance, at the ground also from predatory mammals like fox (*Vulpes vulpes*).

Foraging waters	Breeding colonies	Roosting
Fish density and distribution (+)	Predators (ground colonies) (-)	site security (+)
Fish refuges natural / artificial (-)	Availability of fish and predictability (+)	Availability of fish (+)
Fish behaviour (+/-) e.g. spawning concentrations (+)	Proximity from colony to forage area (+)	Proximity of neighbouring roost(s) (+/-)
Water temperature; thermo conductance (+)	Availability of suitable nest sites (+)	Proximity from colony to forage area (+)
Swimming speed of prey (-)	(Human) disturbance (-)	Wind direction (+/-)
Negative response of fishermen (-)	Negative response from fishermen (-)	Negative Response of fishermen (-)
Collaboration with other species (Pelican) (+)	Existing colonies of Herons / Spoonbills/ Gulls / Egrets (+/-)	
Accessibility (+)	presence of a winter roost (+)	
Proximity to colony or roost (+)	Competition by other Cormorant colonies (-)	
Water depth (-)	Previous use of the area as roost (+)	
Vertical and horizontal migration of fish (+/-)		
High-water floods (+)		
Small rivers (+)		
Structure of rivers / creek / banks (+/-)		
Natural physical gradients (temp. salinity, oxygen) (+/-)		
Resting perches (+)		
Deep sandpits in lake (+)		
Water turbidity (-)		
Anthropogenic influence: disturbance (-)		
Weather (+/-)		

Table 4.2 Factors that contribute to Cormorant numbers apart for foraging waters, colonies and roosts: (+) indicates expected effect to be an increase in numbers with an increase in the factor, (-) a decrease in numbers and (+/-) could increase and/or decrease.

Ultimately, there may be a kind of hierarchy in the number of requirements to be met for the Cormorant in the type of preferred aggregation. The order of the hierarchy can be arranged from day roosts (only some requirements to be met), night roosts (more requirements needed), to colonies (which could be considered 'super roosts') meeting most requirements.

As day roosts are transitory, Cormorants will require a degree of both requirement (1) and (2) but "quality" may not be too important. The main factor here may be close proximity to foraging grounds. Night roosts require more environmental stability/predictability than do day roosts. They may also be considerable distances from foraging grounds. Given the permanence/predictability requirement, there can be a strong traditional element to night roosts. Any type of roost, but especially night roosts, requires shelter from harsh conditions, prevailing winds etc. We may also need to differentiate seasonally, as summer and winter roosts may require different conditions. Summer roosts are more often associated with breeding colonies, whereas winter ones are more often associated with migratory routes and with the birds' winter distribution. Summer roosts may therefore have to meet fewer requirements than winter roosts because of the availability of a nearby breeding colony (i.e. a 'high quality' site).

In Austria in autumn, the first birds to return are young birds on their first migration. They go to the traditional roost sites (15 -20 years established) despite never having been there and without guidance from their parents. Therefore it was suggested that Tinbergen's 4 principles be re-visited: function, mechanism, ontogeny and evolution and ask what is the function of a roost ? Perhaps it acts as an information transfer centre ? In Belgium too, the first birds to return to the wintering places are young birds, but the pattern of roost occupancy clearly differs between autumn and winter. Some roost are typically "autumn roosts" occupied by immatures coming in late summer, and subsequently remaining during the winter period, while some traditional roost sites are only used after November, when the vast majority of adult is present. Autumn roosts tend to be smaller, and more numerous, than the winter roosts. In winter, when birds are more numerous, they seem to congregate in larger roosts, from where they fly each morning to fish mostly in groups (50-200 individuals). Birds fishing together in these groups have left the roost together only a few moments before, which could be an argument in favour of the 'information transfer centre'.

The main principles outlined for roosts also apply for colonies. Protection from disturbance (human/predator) is vital. Cormorants in breeding colonies need to provide for themselves and their chicks. Colonies are traditional, Cormorants are focussed on them for a prolonged period of time. Colonies are required to be stable and predictable and also require a supply of adequate nest material in the proximity. Colonies may be negatively influenced by the proximity of large-sized neighbouring colonies. It is likely that, in these situations, competition for the nearby foraging grounds may occur (Hinterland hypothesis). Parasites (perhaps ticks in rock colonies) may be an important factor for colonies (in Normandy for example). There may be a threshold limit for all these factors below which no colony establishment may be possible. What limits the presence of a colony then depends on the factor that becomes limiting first. Occurrence of Cormorants on foraging grounds depends on the season, location and migration route and adequate access. General 'macro' factors also influence choice of foraging waters, these include the size of water body, fish density, abundance etc.

4.5 Migration and the annual cycle

4.5.1 Ecology, turnover and roost selection in the migratory phase

Typical landlocked pre-alpine lakes and Danube roost site selection (i.e. the colonisation) in Bavaria showed a sequence of events: first Cormorants assembled (i.e. appeared in larger numbers) on lakes, later on rivers and then on small creeks. The effects of shooting Cormorants are (1) an increase in the total number of roosts, and (2) the disappearance of large night roosts. In spite of the shooting of large numbers of birds, the winter population remained stable in Bavaria at the level that had been reached well before shooting started (see Figure 4.5). Some roosts showed high turnover, others remained stable for longer periods. Roost turnover is partly explained by differences in the fish population of the foraging areas involved. Determining the cause and effect in these multi-factorial ecological and demographic field studies is difficult. It was concluded that roosts are sociable systems but not too much is known about their exact function, development or evolution. It is felt that this information was needed with respect to the question of what role roosts role in the exploitation of a particular environment. *Thomas Keller*.

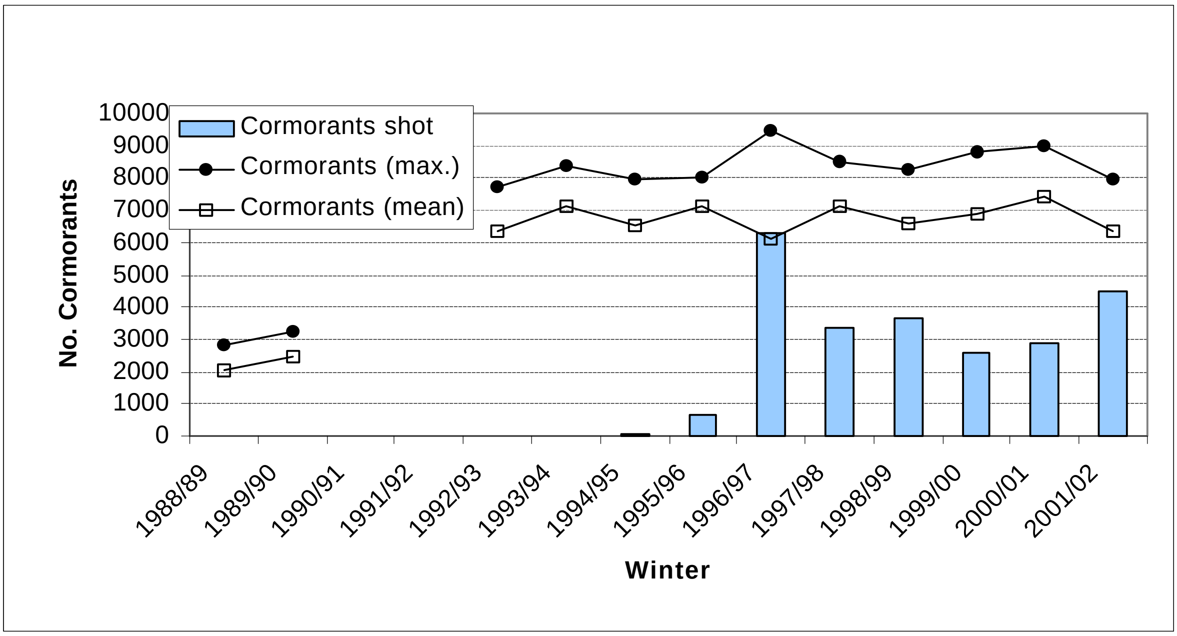

Figure 4.5 Mean and maximum Cormorant numbers (Oct-Mar) and numbers of birds shot in Bavaria, southern Germany.

4.5.2 Ecology and impact of wintering Cormorants in Italy

The situation in Italy was given as an example of a Cormorant wintering country (Figures 4.6 – 4.8). Population dynamics of major lakes and rivers in Italy are best known for the smaller water systems for which fish biomass is quantified. The overall trend in the Po Delta (Figure 4.9) showed that numbers are stabilising, perhaps due to more disturbances of the birds.

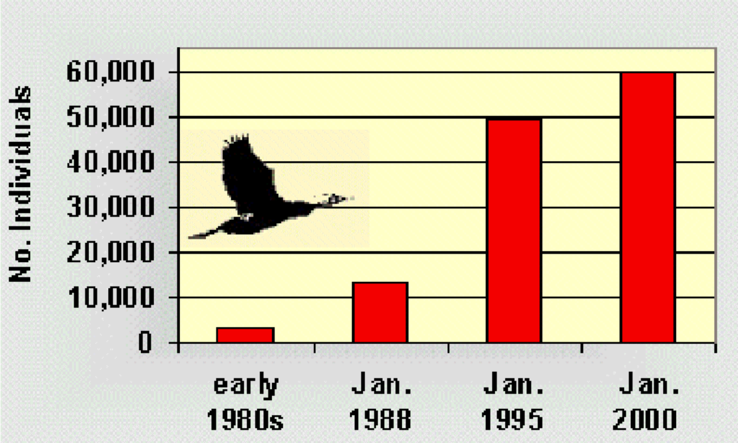

Figure 4.6 Cormorant wintering numbers in January in Italy

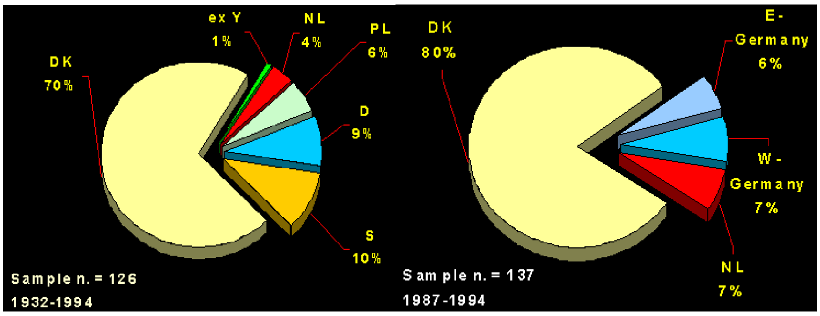

Figure 4.7 Origin of Cormorants wintering in Italy in the north Adriatic coastal area (Po Delta, Lagoon of Venice and Gulf of Trieste) and NW Italy (Piedmont).

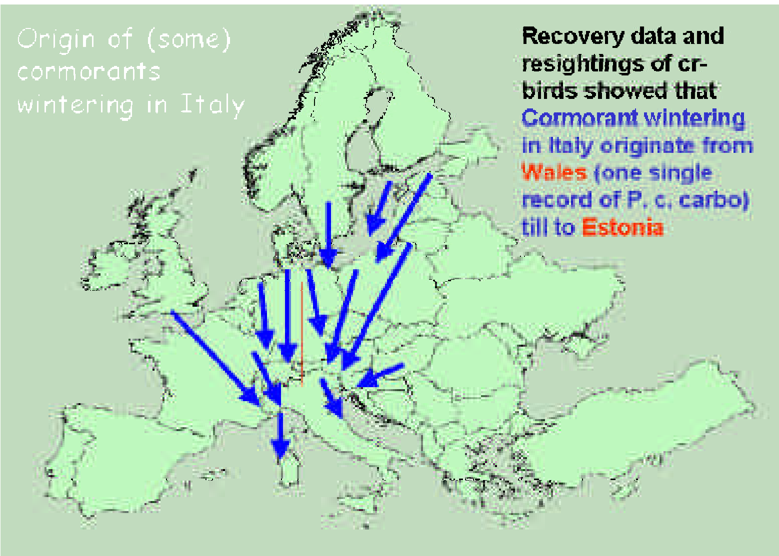

Figure 4.8 Migration patterns of birds wintering in Italy, reconstructed on the basis of ringed-bird recoveries.

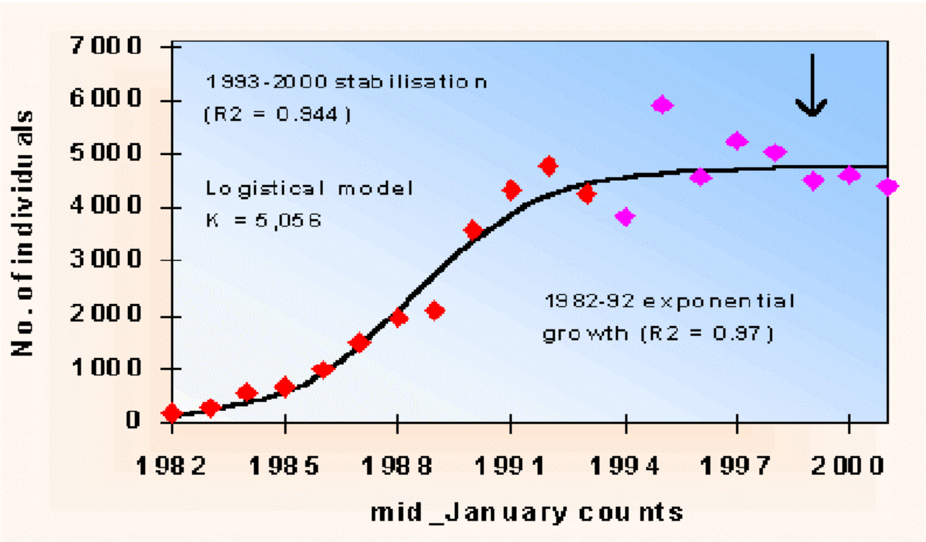

Figure 4.9 Trend of Cormorant numbers in the wintering seasons of 1982-2001 (North Po Delta).

The increase in number of roosts seems to be in accordance with this observation. Furthermore, fish biomass in large lagoons has declined and Cormorants seem to shift to so-called 'fishing valle' (extensive aquaculture systems) and other inland (freshwater) wetlands with high density of fish prey (Figure 4.10). Re-sightings of birds from the Baltic areas, Finnish Gulf and Scandinavia have increased along with the increase in colonies and Cormorant numbers in these areas. In Oristano lagoon (Sardinia) Cormorant numbers have declined after severe disturbance several years ago (from a maximum density of 309 birds/ha, the highest recorded in Italy, to less than 10 birds/ha). However, mild winters are a factor that could be of importance here as well. Most reported conflicts arise in 'fishing valle' areas and coastal lagoons where it is almost impossible to protect against fish-eating birds because of the scale of the habitat. *Stefano Volponi*.

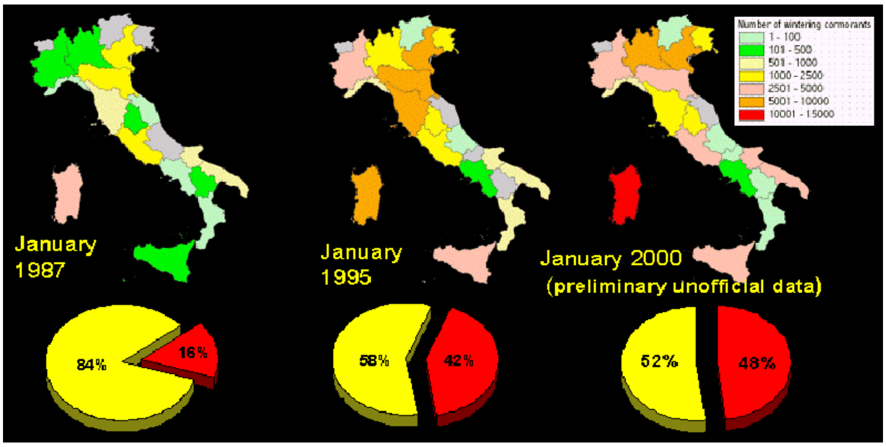

Figure 4.10 Changes in winter distribution and habitat choice (yellow = brackish wetlands, red = freshwater wetlands) from the late 1980s to 2000.

4.5.3 Migration in perspective: large scale patterns in demography and gaps in knowledge

The large-scale patterns on the Pan-European scale are less well known than the national patterns. However, to reach a Pan-European overview certain gaps in our knowledge need to be bridged. Especially, the lack of an integrated winter count in Europe has hampered these large-scale analyses. Based on recent inventories, the overall numbers on the western part of the continent seem to have stabilised. Old strongholds seem to be at their limit and numbers here are stable or even in decline. There has been considerable geographic expansion to previously unused areas in Europe. Especially into areas in the Baltic, the Finnish Gulf and Sweden (see Figure 3.6) where there have been recent increases in the number of colonies and the number of Cormorants. A second core area of distribution is in Eastern Europe, around the Black Sea (Romania, Ukraine). Migration patterns and direction of expansion of these populations is, however, less well described. It is suggested, and confirmed during REDCAFE discussions, that Cormorant numbers are increasing here too and new colony foundation is occurring inland in Ukraine and Russia.

Based on the distribution data from Cormorants colour-ringed in The Netherlands, the gross pattern of movements can be described. It is suggested that a decrease in numbers may have occurred at the southern wintering sites nowadays compared to some 15 years ago. More Cormorants are now tending to winter closer to the breeding areas and this might be confirmed by the international winter count undertaken in 2003. *Mennobart van Eerden*.

4.6 Fish communities and Cormorant diet

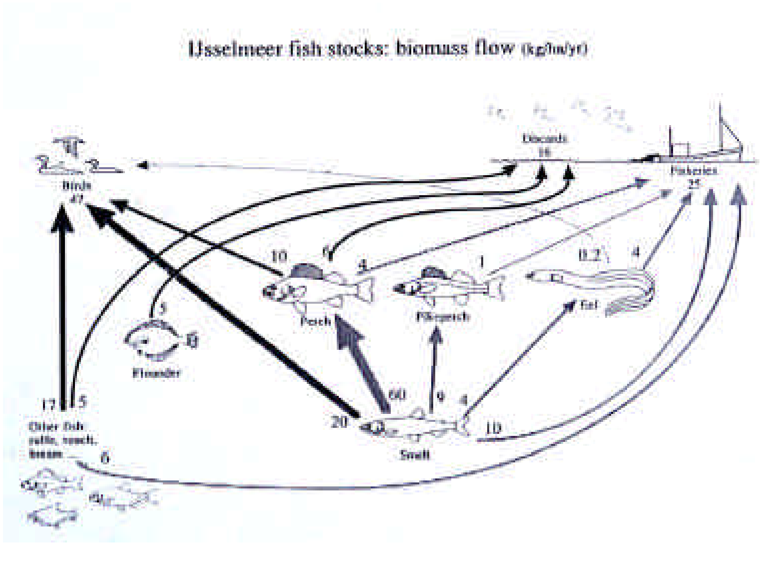

Figure 4.11 Biomass flow (kg/ha/yr) of fish in Lake Ijsselmeer: note that fisheries uptake and discards together are of the same magnitude as the outtake by birds but that, except for some (e.g. Perch), most species differ largely.

4.6.1 Fish community structure in relation to human impact and food availability for Cormorants

Calculations of (a) individual mass and growth rate of fish, and (b) predation rate explain much of the size structure of fish populations. In the Dutch situation, the model PISCATOR uses these parameters to create digital fish populations that closely follow the trends in the natural populations. Worldwide, fisheries manipulation causes a shift of size class to smaller fish (commercial fish tend to be bigger and are taken preferentially). The same goes for Lake Ijsselmeer, comparing 1989 and current distributions of fish length frequency. Trophic interactions may also result in species shifts. For instance, high mortality in piscivorous fish may favour the abundance of zooplanktivorous fish. When zooplanktivorous fish increase, this may result in the increase of algae and, thus, reduced prey visibility for Cormorants (e.g. see 4.3.4). It may also increase algaevorous fish, which will then become more preferable to Cormorants.

In the PISCATOR model, there was emphasis on the strong shift in length class distribution related to fishery pressure. However, no consideration has yet been given in the model to the absolute total biomass involved (though see earlier work summarised in Figure 4.11). The model makes population dynamics calculations purely on the basis of size class distributions. It is therefore less useful if one wants to compare or distinguish between the impact of fisheries and Cormorants on fish stocks. However, insight is gained that size distribution shift is the result of heavy fishery mortality. *Joep de Leeuw.*

4.6.2 Cormorant diet in relation to fish species abundance: examples from Lake IJsselmeer area

An overview of different studies of Cormorant diets in various water systems in The Netherlands shows that the ‘between water system’ variation in diet is large and more than the ‘within water system’ variation. Cormorants thus depend on many water systems and a great variety of fish species (see also 4.2 and section 3.3.4). Systematic sampling of fish within a water body during the course a season and over several years is rare. Therefore, in 1998 and 1999 lake IJsselmeer was systematically fished by RIZA along 21 predefined trajectories that correspond with distance to Cormorant colonies on the near shores. These data were combined with Cormorant diet information (obtained from the examination of fish otoliths recovered from Cormorant pellets) obtained from corresponding colonies. Details of fish species composition, abundance and temperature and size-dependent availability to Cormorants were given. Major conclusions were that: (1) large variation between water systems occurs, (2) fish species composition within one system is rather robust in terms of yearly variation, (3) peak years of fish recruitment are reflected in Cormorant diet. Within the group of fish consumed by Cormorants, a preference existed for Perch, Ruffe and Roach (see Table 3.4 for scientific names), whereas Smelt (*Osmerus eperlanus*) was severely underrepresented in the diet (i.e. it was more abundant in the environment than in dietary analysis). There was also preference for fish ranging in size from 1 - 30 g (range 0 - 450 g). Cormorants thus largely rely upon young fish and small species in this system, showing no selection, apart from the apparent avoidance of small Smelt. *Stef van Rijn*.

REDCAFE discussion: this focussed on the assumed sustained swimming speed and the uncertainties in the catch efficiency calculation of the fishing trawl. Also, the accuracy of estimating fish size from otoliths in Cormorant pellets was discussed. The general conclusion reached highlighted the Cormorant as an opportunistic forager, though the smallest prey are underrepresented presumably because of poor detection in this turbid water system.

4.7 Cormorant ecology and impact on fisheries

4.7.1 Cormorant impacts: perceptions and realities

The Cormorant has various 'roles' in everyday society: from 'nature's wonder' to the 'black plague'. Viewpoints of conservationists and fisheries' stakeholders are often very different (see Chapter 3). The main scientific difficulty with quantifying the 'Cormorant problem' seems to be the definition of impact: it is proposed to define it as the proportion of stock removed versus relative loss due to the take from fishing by humans. The practicality of this approach, however, is low. The issue of the definition of stock as a sum of the recruitment and survival of the older fish is complex. Many factors determine the recruitment and survival and not much is known about the natural survival rates of young fish. Modelling fish populations is a much more developed approach in marine sciences and could be applied to Cormorant–fish interaction studies. Modelling the impact of Cormorant foraging behaviour on fish populations, however, is complicated by the species' ability to switch both prey species (e.g. see 4.2 and 4.5.2) and foraging strategy (e.g. see 4.3.2). The fish size-class model discussed in section 4.6.1, however, so far ignores crucial total biomass estimates. *Ian Russell*.

REDCAFE discussion: this addressed many of the conflict situations across Europe. Some countries showed progress in bridging the gap in viewpoints, others were still split in opposed camps. The question remained if we should make distinction between commercial and sports fishing claims on fishing areas. However, all REDCAFE participants agreed that no distinction should be made between angling and commercial fisheries stakeholders, both having equal 'relevance/importance'. Furthermore, restocking of fish was not viewed as a sustainable ' solution' to the Cormorant problem. Small water bodies are more easily managed and therefore much stocking and manipulations take place in these areas. It was stated that eutrophic habitats tend to have unnaturally structured fish populations and the best way to manage the conflict may well be to ensure the good environmental conditions for fish populations, for example in Greece the management of lakes has become the most important strategy. Public awareness campaigns have helped to resolve issues where pelicans and Cormorants were blamed for lower economic profit. Fishermen often shift to tourism and thus have a stake in protection of bird populations that are interesting to tourists. In Romania in 1990 hunting was banned but the problem remains. Therefore, the perception is that shooting does not affect the birds in a major way. From here discussion went into the issue of shooting Cormorants (see also Chapter 5). Denmark, Romania and other South-Eastern European Countries tended to regard shooting of Cormorants as a tolerable management option from an ecological viewpoint. However, in Romania people tend to prefer to direct their shooting effort towards commercially viable species (e.g. edible or valuable for fur) rather than towards Cormorants. However, people might shoot Cormorants if financial subsidies were available. The argument (referring to studies showing no effect on the overall number of Cormorants) being that shooting does not harm Cormorant populations. This, however, obviously depends on the scale of the shooting. Further, the argument was put forward that shooting may soothe some of the high pitched emotions of people that perceive damage and thus may, to some extend, solve the conflict at the perception level. A view apparently favoured in Denmark for example. Most other counties, however, prefer to limit the danger of uncontrolled dispersion of the Cormorants, particularly across political borders, as this would make management in other regions more difficult. There is also an ethical issue about shooting, which was considered important, but the ethics of Cormorant culling have not yet been considered, publicly at least, across Europe.

4.8 Habitat 'vulnerability' to Cormorants

In this workshop, REDCAFE participants considered 'ecologically relevant measures to alter the vulnerability (or attractiveness) of water bodies to Cormorants’. Here the types of water bodies detailed in case-study datasheets (see Table 4.1) were used. These discussions are summarised in Tables 4.3 and 4.4.

Coastal waters / lagoons / estuaries (100-300 kg/ha)	**Large lakes (eutrophic 200-500, mesotrophic 50-100, oligotrophic 10-40 kg/ha)**	**Large rivers (100 kg/ha)**	**Small rivers (< 100 kg/ha lowland)**
	Prey density (some species / lake / sites)	Prey density (stocking)	Prey density (stocking)
Increase fish refuges	Reduce predictability	Reduce Predictability (stocking)	Reduce Predictability (stocking)
Zonation of disturbed / protected areas helps to keep the birds "locally"	Reduce proximity of roosts/nests	Reduce proximity roosts/nests	Reduce proximity roosts/nests
	Availability of alternative sites	Availability of alternative sites	Availability of alternative sites
	Refuges natural/artificial	Refuges natural/artificial	Refuges natural/artificial
	Improve Habitat quality	Habitat quality	Habitat quality
	Water quality	Water quality	Water quality
Increase predators of Cormorants		Improving fish colonisation	Increase predators of Cormorants
Improve fish colonisation			Human presence

Table 4.3 Ecologically relevant measures to alter the vulnerability (attractiveness) of larger water bodies to Cormorants. Fish standing stock is estimated and indicated in kg/ha.

Clearly, the number of management options, from an ecological point of view, declines with increasing size of the water body (see also 5.8.2). The highest fish density is also to be expected in smaller water bodies. It would be tempting to focus on these smaller waters but that would neglect serious conflicts reported in the Baltic for instance with coastal waters and/or lagoons and estuaries.

Small running waters + gravel pits (50)100-500 kg/ha	Fish farms (stocked biomass 1,000 - 10,000 kg/ha)
Introduce buffer stock (fish)	Introduce 'buffer' species
Adapt timing of stocking	Prey density (introduce seasonality)
Gradual re-stocking	Reduce Predictability
Increase availability, turbidity, barriers	Increase availability, turbidity, barriers
Reduce proximity of roost/nest sites	Reduce proximity of roost/nest sites
availability of alternative sites	Availability of alternative sites
Underwater refuges natural or artificial	Underwater refuges natural or artificial
Increase human presence	Increase human presence
Water quality	location on migration routes/natural habitats
	15 October warning: “increased alert”
	Avoiding; disturbing colonies < 5 km, roosts < 15 km
	Protection by shooting, netting, disturbance etc.

Table 4.4 Ecologically relevant measures to alter the vulnerability (attractiveness) of smaller (artificial) water bodies to Cormorants. Fish standing stock is estimated and indicated in kg/ha.

4.9 Pan-European synthesis

4.9.1 Cormorant distribution

Three maps of Europe were used as background material, one on roosts (partly finished), and two additional ones: a map indicating the locations of Cormorant colonies and another indicating cases of reported damage. In this way, spatial patterns on the Pan-European scale became available for speculation on cause and effect. The main insights of the maps were the many conflicts in the new Cormorant expansion areas and relatively fewer conflicts in the eastern states. Gaps in geographical coverage became clear. After introduction of a prefabricated GIS map of the water bodies in Europe in which a true representation of water and wetland areas with relevance to Cormorants was plotted, some major trends in the geographical location of Cormorant colonies and recent population dynamics were discussed. The ‘water map’ was a good background to understand the Cormorant’s distribution in summer and winter. Moreover, the use of layered maps with distributions of roosts, colonies and damage cases across Europe seems a viable way of improving our pan-European approach to understanding Cormorant distribution in the future.

4.9.2 System characteristics in Europe

In European water systems, we can recognize gradients in the trophic status (Figure 4.12) from the oligotrophic systems in northern countries (e.g. Estonia) and mountainous regions (e.g. alpine lakes and rivers) to mesotrophic and eutrophic systems, which cover a wide range on the continent. Eutrophic systems can be found in delta areas such as the large Dutch water systems. Hypertrophic systems, often manipulated by man, can be found in small, stocked lakes, river sections, deltas and fish farm areas.

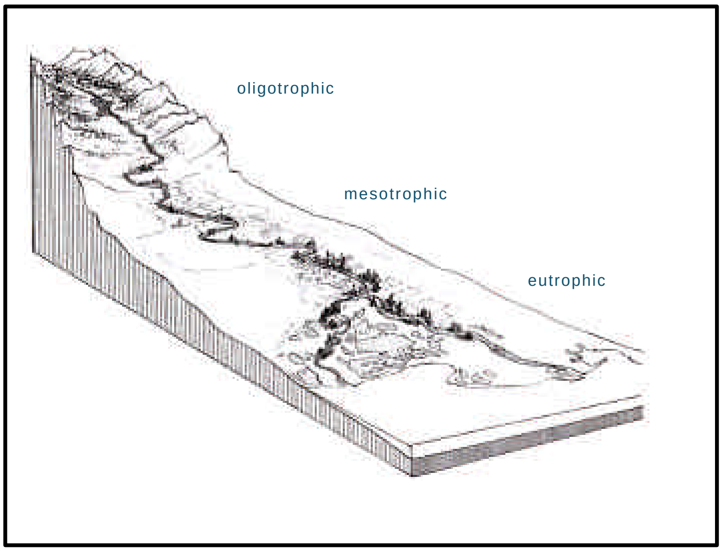

Figure 4.12 Schematic representation of a river system showing natural trophic zones.

To understand the distribution and densities of Cormorants in Europe, REDCAFE participants provided information about water system parameters, fish and Cormorants (see Table 4.1). Information was obtained from 13 countries and 64 water systems (Table 4.5). Although this dataset did not represent a complete pan-European picture, it gave good indications of the relationship between Cormorant densities and water system characteristics. These included natural, semi-natural and artificial waters all with their own specific trophic state. The cases also represented a wide range of habitats from large open seas, estuaries, lakes and rivers to small streams, reservoirs and fish ponds.

Although widely scattered, there was a distinct relationship between the presence of Cormorants and the size of the water system (Figure 4.13). Although there was an overlap in the descriptions of system size, especially between small and medium systems, larger systems were clearly occupied by more Cormorants (see also Figure 3.7). The between-site variation must be explained by other characteristics in the system. Data suggested a tenfold difference in some parts of the intermediate systems (5-100 km^2). Larger systems thus carry most Cormorants on an annual basis and this is an understandable but important finding. It shows that the large scale configuration of Europe, with its large rivers, coastal seas and lakes form the natural basis for the distribution of the species.

HABITAT	Austria	Estonia	Germany	Netherlands	Italy	Belgium	Scotland	Romania	Eng/Wales	Poland	Spain	Greece	Switzerland	France
1. Open Sea		2												
2. Estuaries (+ Brackish Lagoons)		1			5			1			7	1		
3. Inland sea				2						4				
4. Large Lakes			2	1	7		1			3		1	1	1
5. Large Rivers			1		1	1			2					
6. Impounded Rivers			1											
7. Streams/Small Rivers			2								2			
8. Reservoirs/Small Lakes/Sandpits			1	1					6	2				
9. Fish Ponds										3				
TOTAL		3	7	4	13	1	1	1	8	12	9	2	1	1
HABITAT	Austria	Estonia	Germany	Netherlands	Italy	Belgium	Scotland	Romania	Eng /Wales	Poland	Spain	Greece	Switzerland	France
LARGE		3		3	5			1		4	7	1		
MEDIUM			4	1	8	1	1		2	3		1	1	1
SMALL			3						6	5	2			
Oligotrophic		3												
Mesotrophic			5	1	5	1			2	1			1	
Eutrophic			2	3	8		1		2	8	9	2		1
Unknown										3				

Table 4.5 Input data (i.e. number of case studies) from 13 different European countries, in relation to habitat type, system size and trophic state as recorded by REDCAFE participants. Note: this is a biased sample and may not be representative on a pan-European scale: cases were those where conflicts were perceived to occur.

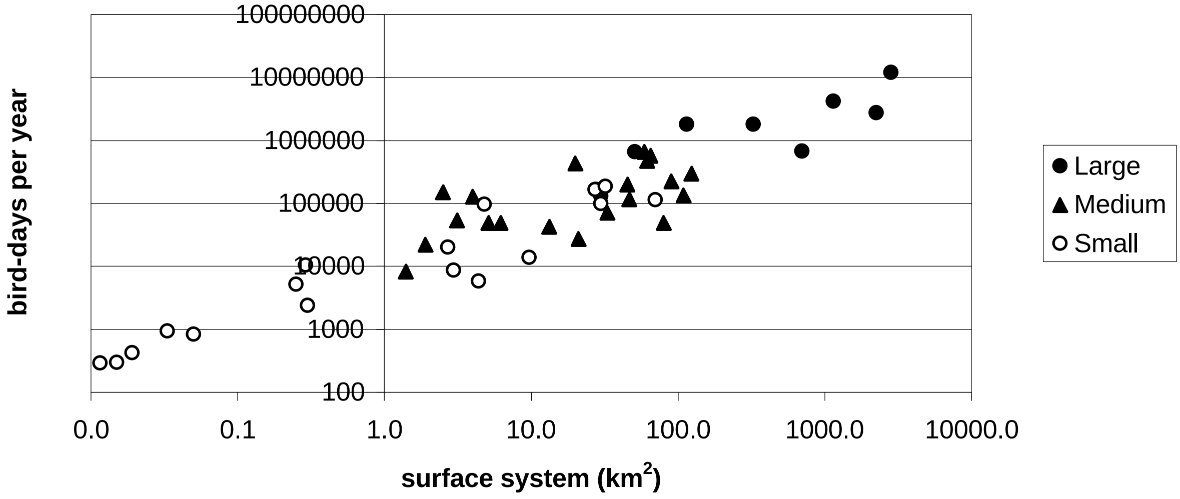

Figure 4.13 Relationship between Cormorant density (bird days/ha/year) and system surface (square km). Note the logarithmic axes. Based on data from 64 case studies (see Table 4.5).

Focussing on actual Cormorant densities (Figure 4.14), clear differences in system types were apparent. Low Cormorant densities occurred mainly in natural and semi-natural water systems, whereas in artificial systems high densities were noticeable. High Cormorant density may thus be related to fish density, which is variable but highest in artificial systems, such as fish ponds and reservoirs.

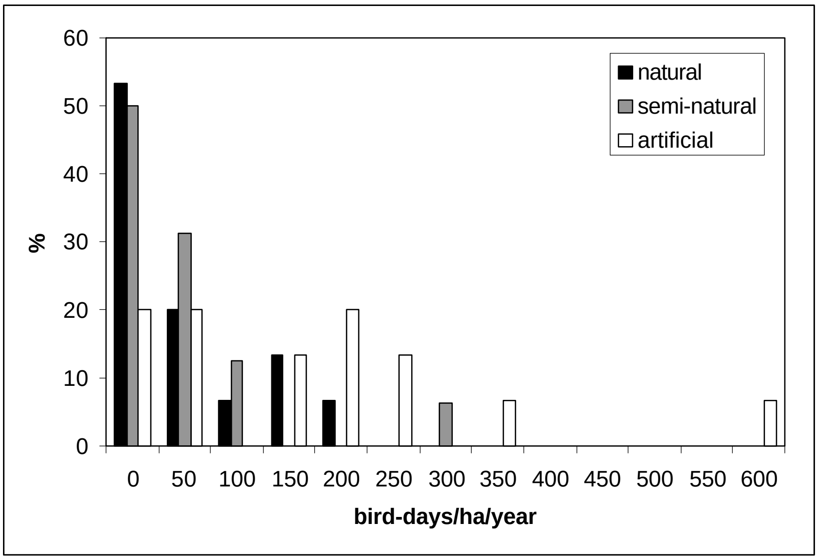

Figure 4.14 Frequency (%) of Cormorant densities for the different system types, based on data from 64 case studies (see Table 4.5).

It would be interesting to estimate impact on fish populations in relation to Cormorant density but this is not easily derived from the available data. For example, the relationship between Cormorant density and the biomass of the most frequently eaten fish species is not clear. This may be expected because generalist predators such as the Cormorant may show only a weak numerical response to changes in density of a particular prey. Another, not mutually exclusive, explanation for this is that there is often very little, or no, rigorous data available on fish biomass (see 4.7.1). Similarly, natural fish population dynamics in fresh and brackish waters are poorly understood. Currently, therefore, the best workable option, in the absence of specific data, is to 'guesstimate' fish biomass based on appropriate data from the scientific literature and site-specific local knowledge and expertise.

Despite the reservations, it was clear from the information recorded by REDCAFE participants that artificial systems had the largest reported fish biomasses (i.e. over 1000 kg/ha) although these were not always associated with the highest Cormorant densities. Some of the artificial systems were associated with the highest Cormorant densities reported whilst natural systems had relatively lower bird densities often with lower fish biomass (Figure 4.15).

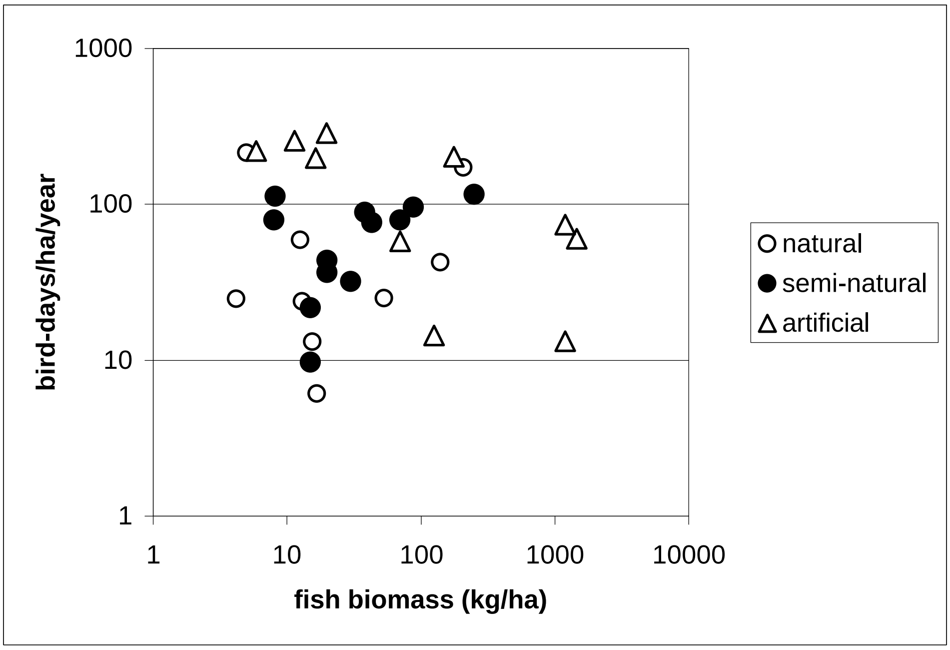

Figure 4.15 Relationship between Cormorant density and fish biomass of the most frequently eaten species for the different system types.

In 37 (58%) of reported cases, information about the fish species eaten by Cormorants was available. It was clear that the largest proportion (>50%) of the most frequently eaten species consisted of Cyprinid fish *Cyprinidae* (Figure 4.16). Other substantial parts consisted of Ruffe (see Table 3.5 for scientific names), Big-scale Sand smelt, and European anchovy (*Engraulis encrasicholus)*. The remaining fishes included many species but only one case reported a commercially important species, the Eel as being the most 'important' food item for Cormorants. This was in accordance with the published literature and other information presented in this Chapter.

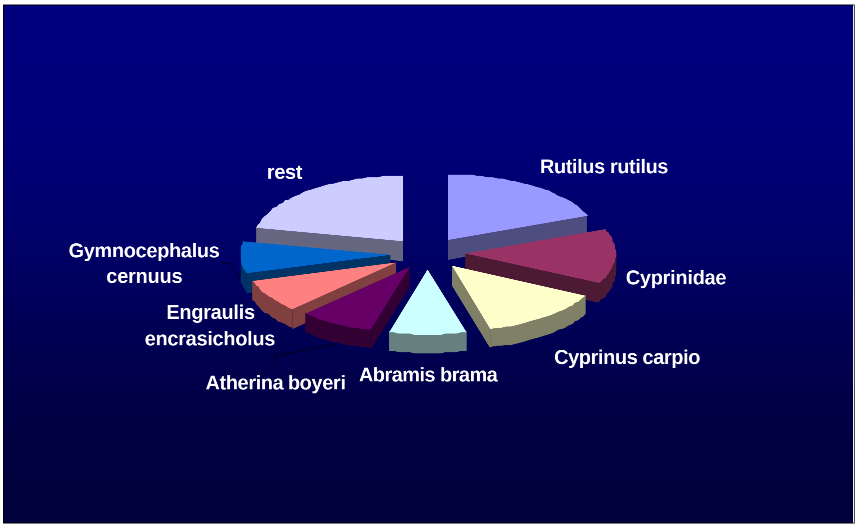

Figure 4.16 Frequency distribution (%) of most frequently eaten fish species (number of cases, n=37, see Table 3.5 or text for common names).

Cormorants are thus opportunistic foragers that may successfully prey on a large number of species, but, depending on aquatic habitat, take common, often small species. The Cormorant is, however, highly flexible in its feeding ecology and in many artificial water bodies such as Carp ponds, feeds solely on these captive fish.

4.10 Conclusions

Three sets of conclusions can be drawn from the information synthesised in this Chapter:

(1) In relation to Cormorants

- Cormorant ecology has been well studied; with respect to numbers, distribution, migratory movements, foraging behaviour and diet it is one of the best known wild living bird species in Europe.

- The opportunistic way of foraging, its great adaptability to a variety of habitats, both freshwater and marine makes it a successful forager which is at present in western Europe at maximum levels, in eastern Europe still expanding.

- This expansion in numbers and area is the result of European wide protective measures, eutrophication, the reduction of pesticides in the environment and alterations of water systems such as dams, sluices which facilitate foraging.

(2) In relation to fish

- Fish species eaten by Cormorants are, for the most part, common, widespread species.

- The heavy fishery pressure in many water systems in Europe has resulted in a shift in size distribution towards the smaller classes, which facilitates Cormorant foraging conditions.

- Fewer large predatory fish are now present because of over-fishing that enables smaller species to expand, and which in turn favours the Cormorant.

- Eutrophication of water bodies has increased the possibilities for Cormorants to exploit larger prey densities.

(3) In relation to damage to fisheries

- Fish species eaten by Cormorants are, for the most part, common, widespread species.

- The heavy fishery pressure in many water systems in Europe has resulted in a shift in size distribution towards the smaller classes, which facilitates Cormorant foraging condition.

- Reduction of eutrophication will decrease Cormorant numbers through reduction in carrying capacity of fishing waters.

- Restoration of waterways, aiming at a greater connectivity will favour fish populations and reduce predation risk.

- In fish farming areas, specific knowledge on prey detection underwater may help to reduce predation of small fish.

- Enlarging fish above the range commonly eaten (i.e.>500 g) may act to reduce Cormorant damage.

- Reducing the conflict involves distraction of birds to quiet areas, thus periods of large-scale Cormorant movements through Europe (e.g. March and October) require extra management attention to avoid the establishment of any tradition to visit stocked water bodies or fish farm areas.

- A combination of ecological, demographical, climatologic and geographic data into a GIS based Decision Support System may help to predict future Cormorant ‘problems’ and reduce current ones by integrated management (see section 3.7) rather than ‘pest’ management.