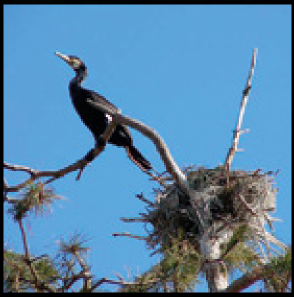
Cormorants and the European Environment

Exploring Cormorant ecology on a continental scale

INTERCAFE



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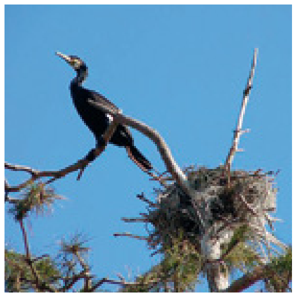

Photographs—INTERCAFE

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ACKNOWLEDGEMENTS

This publication has been produced by **INTERCAFE's** Work Group 1, the 'Ecological Databases and Analyses' group, which comprised 24 researchers from 22 countries across Europe and beyond (for full details of WG1 participants, please see Appendix).

In addition, data on management actions taken against Cormorants at the 'European' scale (see 6.4) were collected and collated by **INTERCAFE's** Work Group 2, the 'Conflict Resolution and Management' group, under the dedicated guidance of Thomas Keller.

Cormorant counts were organised under the responsibility of the IUCN/ Wetlands International Cormorant Research Group (WI-CRG). Through them we would like to warmly thank the thousands of counters, mostly volunteers, for undertaking the breeding and winter counts. Coordinators of the Pan-European winter counts were Loïc Marion and Rosemarie Parz-Gollner. Thomas Bregnballe, Stef van Rijn and Stefano Volponi coordinated the breeding census. National coordinators were responsible for the management of the local networks. The breeding counts (although carried out and owned by WI-CRG) were facilitated by the **COST** programme's **INTERCAFE** network. As such, this allowed WI-CRG to coordinate activities better than before but it also gave them access to new countries and experts — and, ultimately, to new data. Mervyn Roos, Jean-Yves Paquet and Marijan Govedic carried out the GIS tasks and Simon Delany of Wetlands International kindly put the IWC data at our disposal.

Photographs in this publication by courtesy of **INTERCAFE** participants and others, and individual sources are acknowledged under each picture wherever possible.

Information on actions taken against Cormorants (presented in section 10.3) was collated by Thomas Keller through the work of **INTERCAFE's** WG2 ('Conflict Resolution and Management').

This Final Report is a culmination of the work of all of INTERCAFE's Work Group One participants and, as such, is a joint action (see Appendix for full list of people and institutions contributing to this work).

However, in particular, we would like to acknowledge the contributions of Reinhard Haunschmid (Federal Agency for Water Management, Institute for Water Ecology, Fisheries Biology and Lake Research, Mondsee, Austria) for making invaluable contributions, in relation to water and fish databases, to chapter 9 (particularly involving figures 9.1–9.5, 9.8 and 9.9) and chapter 11 (particularly involving the text for section 11.6 and its associated figures) and for providing unpublished data from the Austrian inventory on riverine fishes and Cormorant roosts.

Marijan Govedic, Centre for Cartography of Fauna and Flora, Ljubljana, Slovenia kindly contributed his GIS skills by combining and analysing cormorant, climate and environmental data, particularly to sections 3.4 and 3.5, alongside Mervyn Roos of RIZA who was responsible for the compilation of the Pan-European maps of Cormorant distribution. Considerable input was also provided by Szymon Bzoma (Sea Fisheries Institute, Gdynia, Poland) during WG1's short-term scientific mission (STSM) in Romania, and by Daliborka Barjaktarov (Natural History Museum, Belgrade, Serbia) during STSMs working on the Water Systems Database.

Loïc Marion (University of Rennes, France) and Rosemarie Parz-Gollner (Institute of Wildlife Biology and Game Management (IWJ) at the University of Natural Resources and Applied Life Sciences Vienna (BOKU), Austria) and Thomas Bregnballe (National Environment Research Institute, now Department of Bioscience — Wildlife Ecology, Aarhus University, Denmark) were of invaluable help by organising the pan-European counts of Cormorants, kindly made available to this project by the IUCN-Wetlands International Cormorant Research Group.

Henri Engström, Manfred Enstipp, Mikael Kilpi, Svein-Håkon Lorentsen, Loïc Marion, Karlis Millers, Ivailo Nikolov, Josef Ridzon, Josef Trauttmansdorff and Zeef Arad shared their bird and environmental knowledge, while Emmanuil Koutrakis, Ian Winfield and Catarina Vinagre were of great help in making their fish- and fisheries knowledge available to the group. Finally, in Vienna Rosemarie Parz-Gollner, in the Romanian Danube Delta Botond Kiss, and around the Baltic Sea Mikael Kilpi, Vilju Lillileht and Anna Gaginskaya (of the Biological Institute of St. Petersburg State University) were all of great help in organising and hosting WG1's STSMs.

CONTENTS

As well as compiling ecological data, WG1 devoted quite some effort to discussing relevant topics and perspectives. This publication only summarises the main findings of WG1. There follows an illustration of the detailed recordings undertaken, a small exposé of part of a discussion at a WG1 meeting in Bohinj, Slovenia in October 2006. Such discussions — down to regional level and local, site-specific levels were apparent throughout **INTERCAFE's** work and refer to the basic questions behind Cormorant-fisheries interactions: is there an effect of the birds on the fish and, if so, can we explain it?

Starting from discussions like this, WG1 worked with the available data and tried to quantify relevant parameters and explore apparent relationships.

J: *'Nase populations are going down everywhere, for instance in the Danube catchment — so it's not just a Slovenian issue. The Nase was declining before the Cormorants came'.*

M: *'That is the question. Were the birds the cause of the decline or were the fish vulnerable because they were already at low numbers?'*

Ma: *'Cormorants just changed the steepness of the decline — it was happening anyway.'*

Mt: *'We have seen no recoveries in fish populations after the arrival of Cormorants — and the spawning stock has declined. No population structure data are available. We only have annual catches — but the population has become older and older — all the juveniles are missing. We now breed fish and try to repopulate parts of the upper river Krka. Here the population is now in a better state and 2–4 year-old fish are present now.'*

Photo courtesy of Florian Möllers

1 PREFACE

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

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

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

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

The **INTERCAFE** network comprised almost seventy researchers from all 27 EU Member States (except Luxemburg, Malta and Spain) and other countries in continental Europe (Georgia, Norway, Serbia) and the Middle East (Israel). In addition to these 28 countries, Ukraine and Croatia were also associated with the Action. **INTERCAFE** held a series of eight meetings, each themed around a topic particularly relevant to the host country:

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

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

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

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

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

The **INTERCAFE** publications are:

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

Highlights from these publications will be available in **INTERCAFE**: an integrated synthesis (ISBN 978-1-906698-065) at http://www.intercafeproject.net

Drawing on **INTERCAFE's** ability to develop a network of researchers and the Action's privileged opportunity to see and hear about Cormorant-fishery issues across Europe and beyond, 'Cormorants and the European environment' is an exploration of Cormorant ecology, particularly in relation to interactions with fish, on a continental scale.

Adult male Cormorant (*Phalacrocorax carbo sinensis*), Oostvaardersplassen, The Netherlands.
Photo courtesy of Mervyn Roos.

Nowadays, the Great Cormorant *Phalacrocorax carbo* constitutes a prominent top predator in many diverse aquatic habitats across Europe. Having successfully recovered from a greatly reduced population numbering some 600 pairs in two colonies in The Netherlands in the late 1960s, the species is no longer threatened from a conservation perspective. The spectacular increase in the population of the 'continental' race (*P. c. sinensis*) is considered a success story in terms of nature conservation. A top predator has been reinstated through the joint efforts of protective measures and improving conditions in the aquatic environment (van Eerden *et al*. 2003). As such, the nature conservation goal for the species has been met, parallel with those of other wetland species like Great White Egret (*Egretta alb*a), Spoonbill (*Platalea leucorodia*), White-tailed Eagle (*Haliaeetus albicilla*) and others. The fact that Cormorants are now relatively numerous across their former geographical range and in many places where they were formerly absent, that the species often operates in large flocks, is highly mobile, and a versatile forager across a bewildering diversity of fresh, brackish and coastal waters forms the biological basis for conflict with fisheries' interests (e.g. van Eerden *et al*. 2003, Carss & Marzano 2005, Carss *et al.* 2009). Cormorant ecology and population dynamics have been studied for decades and few, if any, other waterbirds in Europe have been investigated in such quantitative biological detail (van Eerden *et al*. 2003). Nevertheless, there is much still to learn about the ecology of Great Cormorants and their relationship with European wetland environments.

This publication is the result of the joint efforts of a number of researchers during the **INTERCAFE** Action. 'Cormorants and the European environment' takes an integrative approach, bringing together ecological knowledge and data relating to both Cormorants and their fish prey but also relating to wider European environments. The aggregation of information was possible both in the field by meeting local and national experts from a diverse range of sites across Europe during **INTERCAFE** meetings (see page 6), as well as from the literature and unpublished data. This has led to considerable new insights into Cormorant ecology at a large geographic scale. Of particular benefit was the opportunity to integrate information from numerous different sources and to provide knowledge on an EU-27, and even on a pan-European, scale and this is undoubtedly a unique strength of the work of the **INTERCAFE** Action.

One of the main tasks of **INTERCAFE's** WorkGroup 1 was to come up with a coherent view on the population status of Cormorants, the distribution of the species and its ecology. With regard to the latter, the Work Group concentrated on the issue of fish predation and the position of this fish-eating bird in the various aquatic habitats. Emphasis was placed on the ecological factors that determine the occurrence and availability of fish. By using this approach the Work Group attempted to collate a coherent picture of:

- (1) the ecological circumstances under which Cormorants use their habitat,
- (2) how this is related to the abundance and availability of fish species, and
- (3) how the conflicts which fisheries interests fit into this framework.

INTERCAFE's Work Group 1 produced two main outputs, this publication being the result of the main analysis of ecological aspects in relation to European Cormorants, and 'The **INTERCAFE** Field Manual: research methods for Cormorants, fishes, and the interactions between them' (Carss, Parz-Gollner & Trauttmansdorff 2012), which provides an overview of common methods and techniques used in Cormorant-fish studies and which form the basis of much of the quantitative data collated and discussed here.

2 INTRODUCTION

Within **INTERCAFE's** timeframe (2004–2008), Work Group 1 dealt with 'ecology' with the aim of describing relationships between the living world and the abiotic (non-living, usually physical and chemical) environment. With respect to the Cormorant-fisheries issue, this meant unravelling what could be termed 'the Fishes-Cormorants-Human fisheries triptych' and both its environmental and geographical variation across Europe. Therefore emphasis was placed not only on Cormorants but also on numerous species of fishes and their mutual dependence in water systems at the continental scale. Using quantitative food web analysis as a basis, this triptych approach has previously been successfully formulated and applied in the IJsselmeer system in the Netherlands, a long-established foraging and breeding area for Cormorants (van Rijn & van Eerden 2002). The rationale behind this approach is that by quantifying ecological relationships between Cormorants and fish, as well as those between fish and human fisheries, the mutual bonds between Cormorants and fisheries can be better understood. As such it was also possible to relate ecological research findings to the issue of 'conflict' (see also van Eerden *et al*. 2003, Carss & Marzano 2005, Carss *et al*. 2009). **INTERCAFE** addressed this issue by comparing different water systems with respect to the occurrence of Cormorants in relation to the 'availability' of fish, as well as with respect to the timing and site-specific (and site-dependent) aspects of the conflicts.

Part of the ecological work described here was begun on a European scale during the REDCAFE EU-Concerted Action (Carss 2003). However, through **INTERCAFE**, it was possible to extend the original database by adding more relevant information from across the European Union and beyond. Additional information was also obtained from non-EU countries like Israel, Georgia and Iran, as well as by combining information from the IUCN-Wetlands International Cormorant Research Group (WI-CRG) on a much larger geographical scale, that of the Western Palaearctic. This massive area stretches from Iceland, Portugal and Morocco in the west to the Caspian Sea, Turkey and Iraq in the east, and from Greenland and the Barents Sea in the north to Algeria, Egypt and Saudi Arabia in the south. However, the ultimate focus of **INTERCAFE's** work was on the 'European' situation, particularly that pertaining to the EU-27 region.

This publication details the occurrence of two subspecies (or races) of Cormorants in Europe. The first, *Phalacrocorax carbo carbo*, the so-called *'carbo'* or 'Atlantic' race has its main breeding distribution on the rocky coasts of Ireland, the UK, northwest France, Iceland and Norway. The second, *P. c. sinensis*, the so-called *'sinensis'*

Colony of ground-breeding Cormorants ***(Ph.c.sinensis)*** **in a reed bed along the shore of Lake IJsselmeer, Enkhuizen.**
Photo courtesy of Florian Möllers.

or 'continental' race breeds inland, often in trees but also on the ground, across a wide area from France and Italy in the south to the Low Countries, Germany and Poland and north into the countries bordering the Baltic. This subspecies is also widely spread throughout central and eastern Europe from the countries along the Danube catchment area and Greece and extending into Belarus, Ukraine, Turkey, and the Russian Federation and beyond. Although 'carbo' birds breed and generally winter on rocky coasts, there is an increasing trend for inland breeding and these birds can spend prolonged periods inland during the winter. By contrast, *'sinensis'* birds are more generally confined to brackish and fresh waters.

Being a migratory species, the Cormorant clearly exploits different areas in winter and summer. Therefore, a key element of the work reported here was to document these seasonal changes in distribution and numbers across Europe. This was greatly assisted by access to data collected and held by members of Wetland International's Cormorant Research Group. In terms of data collection, synthesis and analysis, this publication includes five related sections, which explore Cormorants and the European environment at a number of different scales, moving between the continental and the site-specific, as follows:

(i) Eight broad aquatic habitat types used by Cormorants throughout Europe are described, with emphasis on their general ecological characteristics and scale. Descriptions are based on expert knowledge and published sources (chapter 4).

(ii) Within these aquatic habitat types, detailed ecological descriptions are given of nine representative areas (most were chosen as case study locations for **INTERCAFE** meetings) at a site-specific level (chapter 5).

(iii) Cormorant numbers and distribution across Europe and beyond are described — often at a very large geographic scale (chapter 6), and these data are explored in relation to prevailing environmental conditions throughout the breeding (chapter 7) and wintering (chapter 8) periods. Analysis and interpretation are carried out within a GIS framework, incorporating independent environmental datasets. Chapter 6 also includes information on management actions taken against Cormorants at a European scale.

(iv) The relationships between Cormorants and their food requirements at specific water bodies are investigated through analysis of 179 site-specific cases across Europe where quantitative (or at least semi-quantitative) data are available for both birds and fishes. This exploration is done under the framework of **INTERCAFE's** Water Systems Database (chapter 9), which also contains information relating to Cormorant conflicts with fisheries interests (chapter 10).

(v) Finally, the exploration returns to the site-specific level by examining some key ecological perspectives of these conflicts (chapter 11) from many of the representative water systems types described previously (chapter 5).

3 METHODOLOGICAL APPROACHES

The main methods used here relied on gathering existing data through contact with local scientists and stakeholders during **INTERCAFE's** international meetings. Such information made a vital contribution to the compilation of the final datasets explored here. Additionally, enquiries were made to numerous researchers in an attempt to collate the best available information about Cormorants in relation to fish in specific waters throughout Europe. As it was commonly felt that the situation across Europe differed considerably, an attempt was made to describe these observed patterns independently by using a geographic information system (GIS). As such, the data gathered during **INTERCAFE** meetings from enquiries (see below) were integrated by working with commonly available EU-wide datasets. Thus information from **INTERCAFE's** Water Systems Database could be explored more deeply and projected to a much wider geographic scale.

The remainder of this chapter provides an outline of the main set-up for the collation of **INTERCAFE's** ecological databases and subsequent analyses at the European scale. Essentially, data collation was undertaken in five integrated modules:

(1) **INTERCAFE** meetings and Case Studies (see Preface).

(2) Additional Work Group 1 meetings.

(3) **INTERCAFE's** Water Systems Database, including enquiries for relevant data from researchers across Europe.

(4) Cormorant census data for status and distribution (breeding and wintering), provided by IUCN-Wetlands International Cormorant Research Group (WI-CRG).

(5) Integration of Cormorant data with environmental and GIS datasets, including ESRI, CORINE and World Climate Data.

3.1 INTERCAFE meetings and Case Studies

INTERCAFE meetings and Case Studies were organised in specific carefully chosen areas where the Cormorant-fishery issues were considered 'typical' of several other places throughout Europe (see also chapter 13 of 'Essential social, cultural and legal perspectives on Cormorant-fisheries conflicts' [Marzano & Carss 2012]). Each of the nine **INTERCAFE** meetings thus explored both a major wetland habitat type on a pan-European scale in relation to Cormorants and fisheries, but each also allowed Work Group 1 to explore a specific ecological issue (see Table 3.1). Work Group 1 addressed the ecological description of each area and tried to add the key data from that region to **INTERCAFE's** database. Contacts with local stakeholders were useful in terms of access to local ecological information but also helped participants to understand the perception of the conflict as well as explore the economic and social factors affecting the local community (see Marzano & Carss 2012). Specific information is discussed through each of the **INTERCAFE** meeting reports (it is planned that these will be available at http://www.intercafeproject.net), while the main conclusions are fully integrated and reflected in this publication. Table 3.1 gives the location, date, theme, major habitat type, and more specific ecological issues explored in each **INTERCAFE** meeting and Case Study.

3.2 Additional Work Group 1 meetings

Several additional Work Group 1 meetings were organised during the Action. These small meetings (see Table 3.2) were directed towards data analysis and the transfer of techniques (standardised methods),

Table 3.1 INTERCAFE meetings and Case Studies: location, date, theme, major habitat type, and more specific ecological issues explored.

Meeting location	Date	Specific theme	Major habitat type	Ecological issue(s)
Lisbon (Portugal)	Jan 2005	Interdisciplinary integration of natural and social science	Atlantic coast, Tagus estuary	Important wintering area of Cormorants, both carbo and sinensis races
Gdansk, Vistula lagoon (Poland)	Apr 2005	Cormorant ecology, commercial fishing and stakeholder interaction	Lagoon, Baltic Sea	Largest colony in Europe, feeding strategy (lagoon versus sea), potential competition with commercial fishery
Saxony (Germany)	Oct 2005	Commercial carp aquaculture	Carp fish ponds (semi-extensive)	Biosphere reserve with carp ponds and alternative water bodies used by large number of Cormorants
Hula Valley (Israel)	Jan 2006	Cormorant-fishery conflict management	Carp fish ponds (intensive), wetlands	Major wintering area for Black Sea Cormorants, important area for aquaculture and other water birds
Bohinj Lake (Slovenia)	Oct 2006	Angling and EU legislation	Alpine rivers and lakes	Small number of wintering Cormorant in an apparently pristine river environment with high conservation value for endangered and/or scarce fish species and widespread stocking for recreational angling
Hanko Peninsula (Finland)	Apr 2007	What to do when the Cormorant comes	Baltic coast	Rapidly increasing breeding population of Cormorants in a coastal environment
Po Delta (Italy)	Sept 2007	Extensive aquaculture systems and relationships between stakeholder perspectives and different spatial and institutional levels	Large wetland complex	Large coastal lagoon system used as extensive fish ponds, very important area for biodiversity used in winter by Cormorant (and Pygmy Cormorant)
South Bohemia (Czech Republic)	Apr 2008	Management practices in a complex habitat mosaic and at local, regional and national levels	Carp fish ponds and large rivers	Carp ponds used by wintering cormorant, complex wetland mosaic with water turbidity issues
Paris (France)	Sept 2008	The management of Cormorant-fisheries conflicts in France and the wider European context	Water bodies at a large country level	Impact of shooting large number of birds on both Cormorant distribution and that of associated conflicts

others were wrap-up sessions between local specialists and included data analysis and reporting. The main aims of these meetings were to (a) discuss how best to organise and analyse data provided from counts of breeding colonies and roosting sites, (b) retrieve data from countries from which no information had been received, and (c) analyse some of the data by use of a Geographic Information System (GIS, see section 3.5).

These additional meetings were also used to produce an overview of the process and structure for data management of the pan-European counts of Cormorant roosts and colonies made available to **INTERCAFE**. The database structures of the pan-European roost and breeding colony databases were also discussed and documented. A quality check of the pan-European Cormorant roost data was also conducted. An overview of the coverage of countries and regions during the pan-European Cormorant breeding colony count was constructed and used as means of trying to retrieve data from countries where no data had been received so far. Decisions were also taken about rules for future access to the data collated. Letters concerning the protocols for data handling and decisions about future access to data were written during these meetings and later mailed

Ringing young Cormorants during an additional Work Group 1 meeting, Kivilaid, Estonia, June 2007.
Photo courtesy of Karlis Millers.

Colour-ringed young Cormorants for studying migration movements, Kivilaid, Estonia, June 2007).
Photo courtesy of Karlis Millers.

to the national coordinators of the Cormorant census.

Two additional meetings were directed to areas where a big expansion of Cormorants had occured recently, the Finnish Gulf in the eastern Baltic and the Danube Delta in the area of the Black Sea, another important European focal point. Both meetings were specifically designed and implemented to transfer methods (bird ringing, taking biometrical data, food analysis and aerial counting) in relation to parameterising these complex habitats in relation to Work Group 1's broad aims.

Table 3.2 Additonal meetings organised within Work Group 1.

Additional meeting location	Date	Main Goal
Denmark, Kälø	February 2007	Water Systems Database
Romania, Tulcea, Danube Delta	May 2007	Methodology transfer
Estonia, Finland, Finish Gulf	June 2007	Methodology transfer
Austria, Vienna	June 2007	Water Systems Database
Belgium, Liege	December 2007	Reporting
The Netherlands, Lelystad	June 2008	GIS analysis
United Kingdom, Edinburgh	December 2008	Writing-up session

3.3 INTERCAFE Water Systems Database

The main aim of this module was to obtain relevant data (from published and unpublished sources) relating to water bodies throughout Europe. Standardised information on fish, fisheries, and Cormorants were acquired as well as background water chemistry (i.e. nutrient status) and topographic information.

An extensive inquiry, based on a standard Excel spreadsheet (see Table 3.3) was sent out to numerous researchers and to representatives of the different countries participating in the **INTERCAFE** Action. By grouping different water bodies into different types, the aim was to collect information on the full array of European water body types whilst taking into account their geographic position and distribution across Europe. This information was then made available for further analysis in relation to eight water body types:

- Open sea/shore
- Estuaries/river deltas
- Inland sea/large lagoon
- Large lakes

Table 3.3 Example of the spreadsheet used to obtain structured data on different water bodies used by Cormorants for **INTERCAFE's** Water Systems Database. Both hydrological and ecological data were requested according to a fixed format. Some cells remained blank if the respondent was unable to provide relevant information.

Name of respondent	Stef van Rijn
Country	The Netherlands
Name of site	Markermeer

Issue	Specification	Data
Habitat-type	see README	3
Location	Greenwich coordinates	52.35N,5.1E
reference(s) of study	peer/non-peer reviewed/anecdotal*	peer
Period of study (give range)	year(s)	1996–2000
Sub-species	carbo-sinensis*	sinensis
Number of Cormorants involved	maximum	15,000
Number of Cormorants involved	bird days per year	680,000
Status of Cormorants	breeding/non-breeding	breeding
Flock size at times of fishing	average number of Cormorants	1,000
Occurrance of mass fishing	yes/no	yes
Juveniles	% of number	12
Size of fishing water	Km^2	700
Water body	natural/semi-natural/artificial	semi-natural
Depth	m	3.5
Trophic status	oligotrophic/mesotrophic/eutrophic*	eutrophic
Turbidity (Secchi depth)	m	0.5
Fish species in area	number	36
Fish species/group most abundant (rank 1)	latin name	*Abramis brama*
Fish species/group most abundant (rank 2)	latin name	*Osmerus eperlanus*
Fish species/group most abundant (rank 3)	latin name	*Gymnocephalus cernuus*
Overall fish biomass	Kg/ha	115
Density of most abundant species (rank 1)	Kg/ha	50
Density of most abundant species (rank 2)	Kg/ha	40
Density of most abundant species (rank 3)	Kg/ha	15
Fish species in diet	number	14
Fish species/group eaten most (rank 1)	latin name	*Gymnocephalus cernuus*
Fish species/group eaten most (rank 2)	latin name	*Perca fluviatilis*
Fish species/group eaten most (rank 3)	latin name	*Rutilis rutilis*
Density of most eaten speciess (rank 1)	Kg/ha	15
Density of most eaten speciess (rank 2)	Kg/ha	5
Density of most eaten speciess (rank 3)	Kg/ha	3
Overall consumption (all fish species)	% taken from available (Kg/ha)	4.4
Consumption of most eaten species (1-3)	% taken from available (Kg/ha)	16.5
Distance of colony or roost to fishing water	Km	3
Distance to nearest colony or roost	Km	14
Distance to nearest alternative fishing water	Km	7
Colony/roost existence	number of years	23
Colony/roost habitat	willow/poplar	willow
	alder/birch	
	ash/oak/beech/birch/lime	
	coniferous	
	ground nesting	
	other	
Population increase or decrease	% average last 5 years (-=decrease, +=increase	

- Large rivers
- Streams/small rivers
- Reservoirs/small lakes, sandpits
- Fish ponds

In total, 179 water bodies were characterised during this process from 26 **INTERCAFE** countries and the responses of a further total of 65 experts. As well as water systems within the European Union territory, additional information was obtained from Norway, Switzerland, Croatia and Georgia. These complemented the dataset because they represented specific examples of water quality, management and/or use by Cormorants.

In the spreadsheet, common characteristics like water body size, location and depth were requested, plus biotic data on fish (total number of fish species, peak standing stock of fish in summer, top three ranking of most important fish species) as well as data on the trophic level and secchi depth (a standardised measure of water clarity). Cormorant abundance and use was requested, as were peak numbers, total number of bird days spent at the site per year, flock size and data on diet (top three ranking of the most important fish species according to dietary studies). The presence of Cormorants was expressed in 'bird days', that is the product of the average number of Cormorants and the number of days that this number is present (for a detailed discussion, see section 2.4 of the **INTERCAFE** Field Manual [Carss *et al*. 2012]). For example, if 200 Cormorants were present for three weeks on a lake, this results in a total of 200 birds x 21 days = 4,200 bird days. The same number is obtained when 600 birds stay one week. Bird days are a useful way to express Cormorant use of an area in relation to the potential impact on a certain water body (for detailed discussion on integrating Cormorant and fish data in relation to 'impact' at fisheries, see chapter 9 of Carss *et al*. 2012).

3.4 Access to international Cormorant census data

Cormorants breed in colonies in summer, where they construct nests either in trees, bushes, or on the ground in reed beds and on bare rock or sand. Colonies occur in the vicinity of larger water bodies in a variety of habitats, often in wetlands, riverine woodlands, coastal forests, remote islands or rocky seashores. Furthermore, artificial structures such as high lighthouses or remote platforms and shipwrecks may also be used. Cormorant colonies can vary enormously in size with some comprising only a few nests whilst the largest ones may contain up to several thousand nests.

In 2006 the most recent Pan-European breeding census of Cormorants was organised under the responsibility of the IUCN Wetlands International Cormorant Research Group. The organisation of the breeding counts was facilitated by **INTERCAFE** through its meetings and the extensive research network established by the Action. **INTERCAFE** meetings offered unique opportunities for the Cormorant Research Group to discuss and coordinate its activities. **INTERCAFE** was also an extremely valuable platform through which WI-CRG could build contacts with new countries and local experts which otherwise would have been difficult to communicate with.

The preparation of the WI-CRG count was carried out by a small group of researchers experienced in counting Cormorant colonies. A technical description of how to count nests and how to enter data into an electronic database was prepared. National coordinators were selected, and contacted by letter and e-mail, prior to the 2006 breeding season. In the field, counts of colonies were generally conducted as counts of Apparently Occupied Nests, defined as nests in use and sufficiently finished to hold one or more eggs. Following Carss *et al*. (2012), a colony was defined as a group or groups of nests that are within 2,000 m of each other. Such neighbouring groups were referred to as 'sub-colonies' (for full information on the standard methodologies for counting breeding Cormorants see section 2.2 of Carss *et al*. 2012).

In winter, Cormorants disperse over large areas in both freshwater and shallow marine waters. Birds aggregate at night in roosts, situated on islands, in trees and bushes in wetlands, on river banks or artificial constructions like high tension poles, lighthouses, ship wrecks, and dikes. Although winter and summer areas overlap, most birds breed at northern latitudes and winter more to the south. During daytime, foraging flights occur between colonies or roosts and feeding areas and may range between 5–25 km (max. 40–60 km) in each direction. In Europe counts outside the breeding season are best undertaken at night roosts. However, in some areas only daytime counts exist, and these were included to complete the picture of winter status and distribution.

Cormorant counts in winter require coordinated action by skilled persons, using binoculars, telescopes and other techniques such as aerial photography and ship-based counts in large, inaccessible areas. Roost counts are carried out using standardised methodology, over a specific allocated time period for counting and using pre-printed forms (for further information on the standard methodologies for counting roosting Cormorants in winter, see section 2.3 of Carss *et al*., 2012).

Thus two datasets were ultimately made available to **INTERCAFE**, both being the most up-to-date and geographically widespread available — a breeding count at colonies in summer 2006, and a winter roost count undertaken in 2003. Data from both counts were transformed during the **INTERCAFE** Action into a uniform 50 x 50 km grid across Europe (see section 3.5) in order to relate the data to environmental parameters. A basic 'layer' was produced with 885 geo-referenced colonies from all European countries (plus Turkey and Iran) for further multi-layer GIS analysis (conflict cases, climatic conditions and geographical location). For the winter 2003 roost count, a geo-referenced database (and corresponding maps) were produced from more than 2,500 roosts across Europe.

3.5 Environmental and GIS datasets

All the spatial information layers were processed using the Geographic Information System software ArcGis 9.1 (ESRI). The 'Lambert Azimuthal Equal Area' projection was used for making charts in the coordinate system ETRS 1989. A 50 km x 50 km grid was applied to all layers. For each 50 x 50 km cell of the grid, several calculations were made, based on the climatic or water information dataset (see below), but also on the number of Cormorants counted during either the 2003 winter roost counts or the 2006 colony count. The following environmental variables were calculated for each grid cell:

- average minimal temperature in January (°C)
- surface area of shallow sea water (ha)
- surface area of freshwater lakes (ha)
- surface area of each Strahler type river section (ha)

Along with these variables, latitude and longitude were also used as 'spatial variables' and as a proxy to geographical situation (i.e. distance to main breeding area).

This GIS-module aimed to explore geographically the ecology of Cormorants in Europe by combining two ecological datasets (the distribution of Cormorant colonies and winter roosts) with climatic data and data on the type and spatial distribution of waterbodies across the continent. This work was divided into four blocks, focusing on the following subjects.

1. Climatic data

Cormorant distribution across Europe was explored through a spatial and temporal analysis of general climatic patterns. For this analysis temperature data from www.worldclim.org (data Version 1.4 [release 3]) were used, specifically the mean, minimum and maximum temperatures (1950–2000) for each month, averaged per grid cell. The available temperature grid data had a resolution of 30-arc d, often referred to as 1 km spatial resolution (Hijmans *et al*. 2005). All analyses were done with Excel (Microsoft), ArcView 3.3 (ESRI), ArcGis 9.1 (ESRI) using different extensions (Spatial Analyst, Get Grid values) and Scripts (clipgrid) where necessary.

From the original database of Cormorant colonies, a shape file was produced. In ArcView temperature values from grid climatic data were added to colonies as attributes. The 'Map query' tool was then used to explore the temperature grid files. In order to investigate how different climatic conditions across Europe might predict the suitability of a region for Cormorant colonies, the start of breeding activity in a colony was assumed to be related to average spring temperature. Temperature changes for each colony site were then determined for a time, three months after the potential start of breeding, which was assumed to be the time at which young Cormorants leave the colony. The broad rationale behind this approach was the relationship between ambient temperature, water temperature and its oxygen content, and the swimming speed of fishes, which in turn determine the suitability of a region for Cormorants based on the availability of their prey.

2. European Water Chart

Cormorant distribution across Europe was further explored through comparison with a compilation of existing geographical information from CORINE and ESRI on the occurrence of different water bodies in Europe. With the emphasis within these datasets on rivers and lakes, additional information was also included on other water bodies such as shallow coastal systems. Validation of the database for specific areas showed considerable deviation for coastal water bodies (deltas, lowland lakes, oxbows and backwaters). These topographic aberrations have been repaired where possible, using satellite images obtained from the Internet (e.g. Google™ Earth).

3. Cormorant ecology data

The 2003 winter count data and the 2006 colony count data were explored in relation to datasets of both climatic variables and the availability of water bodies (rivers, lakes, coasts etc). Based on the 50 x 50 km^2 gridcell information, Cormorant distribution was correlated with environmental factors at the same level, thus allowing analysis of multiple factor effects.

4. Conflict cases

The REDCAFE EU-Concerted Action attempted to produce a broad-brush picture of the distribution and scale of reported conflicts with Cormorants. Whilst there were certain limitations to this approach, the resulting picture was considered the best available at the time (see Carss 2003, pp.78–102, particularly sections 4.1 and 4.9). This dataset was updated during **INTERCAFE** and the distribution of reported fisheries conflicts with Cormorants was also included in **INTERCAFE's** GIS analyses, firstly in relation to the WI-CRG database of breeding colonies. Quality checks were made of the conflict data file from REDCAFE and, subsequently, a spatial analysis of conflict cases was performed in relation to the distribution and abundance of water bodies and the distribution of Cormorants in both summer and winter.

Table 3.4 Number of countries where conflicts were reported during **INTERCAFE** and **REDCAFE** projects, as well as the total number of conflicts. As some countries and conflicts were reported in both projects, there is overlap between datasets and so figures cannot be totalled across rows.

Conflict details	REDCAFE Concerted Action	INTERCAFE COST Action
No. of countries	23	15
Total No. of conflicts reported	238	200

Table 3.4 above shows the total number of conflict cases used in this study, as well as the number originally obtained by the REDCAFE project. In some regions/countries there were no new conflict cases and so only one source is shown on the resulting map.

5. Analysis

Countries

With respect to country borders, the shape file COUNTRY from ESRIDATA_EUROPE was used initially. However, as this file was incomplete, especially for Northern Africa, the Middle East and Russia, more recent files were obtained from ESRIDATA. The coastline of North Africa and specific areas such as large interior lakes and the deltas of large rivers were incorporated from Google™ Earth satellite images.

Raster

In order to arrive at a rectangled grid system we used the Lambert Azimuthal Equal Area Projection, ETRS 1989. Minimum and maximum X and Y coordinates of the adjusted COUNTRY shapefile were used to arrive at a grid of 50 km x 50 km across Europe. This grid (RASTER50000) was then used as basis for calculations and GIS presentations.

Rivers and lakes

For rivers and lakes, the 'River and Catchment Database for Europe, Version 2.0 (CCM2) — 2007 (Joint Research Centre)' was used. See also website: (http://ccm.jrc.ec.europa.eu/php/index.php?action=view&id=24). The CCM2 database covers the entire pan-European continent, including the Atlantic islands, Iceland and Turkey. It also includes a hierarchical set of river segments and catchments based on the 'Strahler order' system (see Table 3.5) for different tributaries of a river system, a lake layer and structured hydrological feature codes based on the Pfafstetter system. This allowed calculations on the quantitative presence of different water bodies at a continental scale.

This database was available as a Geodatabase only and because **INTERCAFE's** analyses were in ArcGis 9.1, all individual files were downloaded and transformed into shapefiles, 'CCM2-rivers' and 'CCM2-lakes'. Using the adjusted dataset COUNTRY, the layers CCM2-rivers and CCM2-lakes were clipped and stored again. This

The Danube in Serbia is one of the few large rivers of the category 'Strahler 10' in Europe.
Photo courtesy of Daliborka Stankovic.

resulted in a greater reliability of the areas in Eastern Europe.

Procedure

In the file **CCM2-rivers**, river sections were coded according to the Strahler system. Type 1 is most upstream and thus the smallest; type 10 is used rarely in Europe, only occurring in the largest catchment areas such as the River Danube. The Strahler system counts with all confluences in a logic order. According to the general knowledge of **INTERCAFE** participants from different areas in Europe, an average value for river width was given to each Strahler category within the system as shown in Table 3.5.

Table 3.5 River sections according to different categories of the Strahler system, with standardised width based on local observation in the field (Strahler category 10 was provisionally given the same width as Strahler category 9).

Strahler category	Average width (m)
1	3
2	7
3	15
4	30
5	60
6	125
7	200
8	500
9	1,250
10	1,250

Values for river length and width, and thus surface area, were computed for each river section and added to each grid cell in RASTER50000. Using an ID number in the output table, the calculated data could then be presented graphically on a map. The same procedure was followed for lakes in CCM2-lakes, using total lake size for each grid cell.

Shallow coast

For shallow coasts no basic charts were available for all areas in Europe. Consequently, bathymetric data with larger intervals in class width were used to arrive at a best estimate for each grid cell. By using topographic atlases and digital maps of smaller areas the availability of shallow water was assessed. The focus was on shallow water because this is most suitable as feeding areas for Cormorants. Based on published research, 'shallow water' in relation to foraging Cormorants was defined as that up to 25 m deep. Using the files RASTER50000 and COUNTRY the surface area of coastal water could be calculated. The derived file **SHALLOW COAST** combines depth class (i.e. less than 25 m) and surface area for each grid cell. Given the unique nature of this analysis, this was the first European-wide estimation of this 'shallow coastal water' parameter.

Total water

A chart **WATER_HA** was constructed using data from **CCM2-rivers**, **CCM2-lakes** and **SHALLOW COAST**. For each grid cell, the total surface area of water suitable for foraging Cormorants (i.e freshwater and shallow coastal waters) was calculated. The smallest river sections, categorised as Strahler-1, were excluded from this calculation as they were assumed from the literature to be unsuitable as Cormorant foraging waters.

Statistical analysis

Statistical analyses were performed on the raw or modified data in the databases. Common procedures included calculation of means, standard deviations, ranges and frequency distribution of various parameters. Variation was presented as 95% confidence limits around the mean. Standard statistics were performed in Excel, SAS a.o., and multivariate statistics were performed using SPSS. Principal Component Analyses were conducted in Minitab 12.2, and where appropriate, values were log-transformed to obtain normal distributions.

4 AQUATIC HABITATS AND USE BY CORMORANTS IN EUROPE

Cormorants use a variety of water types as foraging sites (see reviews in Cramp & Simmons 1977, Johnsgard 1993, Nelson 2005). Research experience and information from **INTERCAFE** participants was used to describe the major pattern of water types across Europe and beyond. As the variation in landscapes and aquatic habitats is huge, a basic system was used to distinguish between the most important water types. This approach is not exhaustive but merely provides a simple overall view of the existing variation within and between basic water types occurring in Europe. Furthermore, it also emphasises 'scale' as an important factor/variable associated with these habitats. A description of how Cormorants use these habitat types, both in summer and in winter, follows. Again, this is based on available published sources collated through the **INTERCAFE** network.

4.1 Landscape and ecosystem descriptions

The following brief description includes each of the main categories of water systems types. Emphasis is placed on the general characteristics and scale of the system, including biological data, particularly with respect to the occurrence of fishes.

Open sea/shore

This habitat category includes large-scale, open shallow waters and coastal areas. Areas comprise in excess of 10–1,000 km^2 of similar habitat, which is considerably larger than any other water habitat type. Cormorants use coatal waters throughout the year, particularly the *carbo* race whose breeding distribution is mainly restricted to the northwestern coasts of Europe. This race also forages off coasts in winter but is probably somewhat limited by both the movement of fishes into deeper water and poor weather conditions at this time of year — and so many birds make extensive winter movements to freshwaters inland. *Sinensis* birds also use coasts throughout the year, generally the more sheltered continental coasts of the Baltic Sea, Kattegat and Skagerrak, and the eastern North Sea in summer and the western Baltic, Kattegat, Mediterranean, Adriatic, Aegean and Black Seas in winter.

Coastal water clarity (and hence visibility for foraging Cormorants) in the sea can be highly variable, being clear, turbid or extremely murky under certain conditions. However, as a rule, most seawater

Coastal habitat along large open sea, nests constructed of bladder wrack (*Fucus* spp.), Horsens Fjord, Denmark. The breeding adults are used to regular visits to the colony by researchers. Photo courtesy of Thomas Bregnballe.

is clearer than freshwater systems. In some cases brackish (or even fresh) water dominates at the large scale within this habitat category. In Europe this is the case in the Baltic Sea, where a declining salinity influence occurs from west to east, leading to almost freshwater conditions in the eastern regions (Gdansk-Turku) as well as the top of the Gulf of Bothnia. Similarly in the Black Sea area, extensive brackish waters occur in the Sea of Azov regions in the Northern part of this system.

Around seas, coasts may either be rocky (in summer many of these are often seabird cliffs), as is the case along the Atlantic coasts of Europe, at many places along the Mediterranean coasts and along the southern shores of the Black Sea and occasionally in the Baltic. Sometimes, the rocks are relatively low, often rounded boulders with numerous low stony outcrops and islets shaped by land ice (e.g. in the Baltic). Coasts also may also include beaches, sand spits, dunes, mudflats and foreshores. Across Europe, the main prey of Cormorants on the coast fall into three broad categories, each associated with a different habitat. As a result of differences in geomorphology, the coastal seafloor is sandy or muddy and sometimes contains extensive aggregations of stones or bare rocks. On soft substrates (sand and mud) lacking cover, the first fish community tends to comprise benthic (bottom-living) species such as Flatfishes (particularly Pleuronectidae), Gobies (Gobiidae), and Eel (*Anguilla anguilla*). In rocky situations, the dense underwater growth of macro-algae (large seaweeds) gives rise to a complex underwater habitat, providing diverse habitats, food and shelter (cover) for numerous fishes. This rocky-algal community includes Eelpout (*Zoarces viviparus*), Gobies and Sculpins (Cottidae), and Wrasses (Labridae) in more exposed places. On sandy bottoms analogous habitats are often provided by Eelgrass (*Zostera* spp.) beds and these habitats are frequented by similar species to rocky areas with algal cover. Finally, over both rocky and soft substrates, a third broad fish community comprises several 'pelagic' fish species that live in the water column (as opposed to close to the bottom). These are often juvenile individuals exploiting the relatively sheltered shallow coastal waters and include Herring (*Clupea harengus*), several members of the Cod family (Gadidae), and Capelin (*Mallotus villosus*) in the far north. Evidence suggests that in some regions, fish populations and communities in regions like the Baltic Sea have been strongly affected by human activities such as nutrient enrichment and heavy exploitation (e.g. see chapter 13).

Estuaries/river deltas

Estuaries are dynamic ecosystems, being semi-enclosed coastal water bodies where the mouth of a river (usually surrounded by expanses of flat land) has a free connection to the open sea and within which there is a constantly changing mixture of salt and fresh water. Because of the high sediment load from rivers, many estuaries are characterised by large areas of intertidal flats and muds.

River deltas form when a river meets the sea and water flow is no longer confined to its channel and the river expands in width. This causes a reduction in flow velocity and sediment drops out

The delta of the River Danube is one of the most complete estuarine habitats in Europe. Besides Cormorants, the area hosts the major European part of the Great White Pelican (*Pelecanus onocratulus*) population.
Photo courtesy of Botond Kiss.

and deposits. Over time, this single channel will build up pushing the mouth further into the standing water. As this happens, the slope of the river channel decreases and it becomes unstable and the river can breach banks and cut new channels, ultimately resulting in a mature delta with a distributary network of channels. A similar network can also be achieved if a river deposits mid-channel sand/gravel bars at its mouth and is ultimately split into several distributary channels.

Lagoon in the Po Delta, Italy: an example of large-scale shallow water with numerous oyster racks, often used by Cormorants as roosting place.
Photo courtesy of Stefano Volponi.

Estuaries vary greatly in size but are generally in the region of 1–10 km^2, although the Wadden Sea from Texel in the Netherlands to Esbjerg in Denmark is the largest estuarine area in Europe at about 10,000 km^2. Some estuaries can also form into huge deltas. For example, the Po Delta in northeast Italy covers over 520 km^2 whilst the Danube Delta in Romania and Ukraine covers some 5,800 km^2. Whilst not all of the delta territory is open water (much of it is reedbeds, woodland, shrubs and meadows), the areas of surface water can amount to 10s, if not 1,000s, of hectares. Being located in lowland areas close to the sea, estuaries very often connect several different water systems. Riverine freshwater mixes with seawater giving rise to brackish water zones that vary in size depending on river discharge and tidal movement. Lakes, coastal waters, isolated tributaries and oxbow lakes all form different elements, making many estuarine habitats very diverse. Terrestrial vegetation cover in estuaries is mostly low, consisting of marsh vegetation such as Reeds (*Phragmites australis*), Sedges (*Carex* spp.) and Reedmace (*Typha* spp.), with scattered Willow (*Salix* spp.) bushes and forests on the higher levees. However, the slow-flowing, and often relatively warm water of estuaries, often coupled with nutrient-rich waters and substrates means that aquatic plants usually flourish in estuaries and deltas.

Fish species composition in estuaries is often very diverse and the distribution of many species changes with season. Apart from the species commonly associated with either fresh or salt water habitats (e.g. Cyprinids, Pike (*Esox lucius*), Perch (*Perca fluviatilis*) and Herring, Gobies, Gadidae, respectively), many brackish water species also inhabit estuaries. These include Flounder (*Pleuronectes platessa*), Eel, Smelt (*Osmerus eperlanus*), Grey Mullets (Mugilidae) and Sea Bass (*Dicentrarchus labrax*). At certain times of year, migratory fish such as Brown Trout (*Salmo trutta*) and Atlantic Salmon (*S. salar*) will also pass through estuaries on migration to (in spring) or from (in autumn) the sea. Many estuaries have been under human pressure for a long time, factors include building and urbanisation, the disposal of industrial and domestic waste, or the reclamation of land for industry and agriculture. These factors have inevitably also affected both fish populations and the composition of estuarine fish communities.

Inland sea/large lagoons

Some freshwater lakes are so huge in surface area that they are often called ‘inland seas’. Very large lakes in this category were often isolated from the sea because of geological processes as is the case with lakes Peipsi (3,500 km^2) between Estonia and the Russian Federation), Ladoga (17,981 km^2), and Onega (9,894 km^2) both in the Russian Federation. Other inland seas were actually cut off from the sea by man, such as the IJsselmeer/Markermeer (1,800 km^2) in The Netherlands. These lakes are rather shallow for the greater part, being around 10 m (but up to 120 m) deep. By contrast, others like Lake Geneva (582 km^2) between Switzerland and

France is a deepwater lake (372 m average depth), are in mountainous landscapes. Deepwater lakes in central Europe rarely freeze over, which makes them attractive wintering habitat for water birds, including Cormorants.

Many of the shallow large lakes have generally similar fish communities. For instance lakes Peipsi, Ladoga, and Onega have around 30–60 fish species which include shoaling Cyprinids such as Roach (*Rutilus rutilus*), Bream (*Abramis brama*), predatory species such as Perch, Pike and Pikeperch (*Sander lucioperca*), Salmonids and close relatives (including Brown Trout, Arctic Charr (*Salvelinus alpinus*), Whitefish (*Coregonus* spp.), Grayling (*Thymallus thymallus*), and other species such as Burbot (*Lota lota*), Ruffe (*Gymnocephalus cernuus*) and Smelt. Deeper large lakes often contain communities of coldwater fishes including Brown Trout and Whitefish, with predatory fishes such as Pike and Perch. Where waters are warmer (usually at lower altitudes), fish communities will also include Cyprinid species like Roach and Bream. Both eutrophication (nutrient enrichment) and acidification have drastically changed the fish species composition and biomass in many very large lakes. Furthermore, there are commercial fisheries for many fish species here, often operating for many decades, which have also altered the community structure of fish stocks in many places. As a result, several lake restoration programmes have been initiated, including fisheries management measures and re-stocking projects. Fish communities in the large IJsselmeer and Markermeer lakes (some 1,800 km^2 in total) in The Netherlands have been well studied and here Perch and Pikeperch have been harvested intensively. The fish community has shifted as a result and become dominated by Smelt, Ruffe and small Cyprinids. Modelling suggests that with the absence of commercial fishing, the amount of predatory fish would increase strongly and the amount of small (prey) fish decrease by 40–50% (van Nes *et al*. 2002). However, such broad predictions must be treated with caution, as knowledge of the density-dependent mechanisms regulating fish numbers is far from complete.

Coastal lagoons are areas of shallow, coastal salt water, wholly or partially separated from the sea by sandbanks, shingle or rocks. Lagoons show a wide range of geographical and ecological variation and the water in them can vary in salinity from brackish (owing to dilution of seawater by freshwater) to hypersaline (i.e. more salty than seawater as a result of evaporation). Lagoons vary in size but may be around 30–100 km^2 in southern Europe for example and are invariably shallow with a mean depth of no more than around 10 m (and often considerably less).

The plant and animal communities of lagoons vary according to site-specific physical characteristics and the salinity regime. Although, compared to other marine habitats, lagoons hold only a limited range of fish species, many are adapted to the varying salinity regimes of lagoons and some are unique to these habitats. In coastal regions, large lagoons share similar aspects with some large shallow inland seas. Lagoon waters are often brackish but can occasionally be fresh water as is the case on the Baltic coast of Poland and Lithuania. Lagoon fish communities are often dominated by Sand-smelts (Atherinidae), Mullets and Gobies, depending by salinity, sediment and turbidity. Fish distribution changes seasonally in an annual cycle of resident species (which move into deeper waters in autumn/winter) and the spring/summer migration of juveniles between coastal areas and lagoons. Lagoons are important nursery areas for many species. Like estuaries, lagoons are highly sensitive to anthropogenic pressures such as commercial fisheries.

Large lakes

Large lakes are generally somewhere up to around 100–1,000 km^2 in area and their depths can be highly variable, changes in water level occurring naturally. In general, this means the lowest levels occur in summer and autumn and highest ones in late spring. Lake morphology is highly dependent on surrounding landscape. In mountainous terrain, lakes are often relatively small and deep (commonly up to 100 m) whilst in riverine habitats at lower altitudes they tend to be larger and shallower (commonly less than 30 m and often considerable shallower). These surrounding landscapes also often determine the general nutrient status of lakes, upland lakes tending to be oligotrophic (nutrient poor) and lowland ones eutrophic (nutrient rich). Islands in lakes are often afforested because they are not grazed and they also usually lack carnivorous predators and are relatively undisturbed by man. This makes these sites particularly attractive to both

Lake Kinneret or Sea of Galilee, Israel with extensive reed beds and Cormorant roost in winter. Photo courtesy of Stef van Rijn.

breeding Cormorants and for the establishment of roosts. The shallowest lakes (2–15 m deep) freeze easily during winter and populations of waterbirds are then forced to move.

Lake fish communities are similarly influenced by the morphology, and ultimately the location, of lakes. Thus, Salmonids and Coregonids tend to dominate in oligotrophic (upland, colder, deeper) lakes, Cyprinids in eutrophic (lowland, warmer, shallower) lakes, and Perch (and sometimes Pike) are commonly found in both types. If connected to a river system, fish stocks (particularly Salmonids) may migrate further upstream in order to spawn and/or migrate to the lake to over-winter. As a response to cooling water temperatures in autumn, many fish will move down to the deeper parts of the lake as the season progresses. The shallow fringes of lakes are often important spawning areas for fish as are the seasonally flooded lake margins. Lake fish communities can change rapidly as a result of species introductions, massive fish kills (caused by anoxia, disease or overpopulation), and exploitation by fisheries. This is particularly true if the species harvested are top predators (see example of IJsselmeer on previous page).

Large rivers

River sections of the largest category are very wide, slow running waters. These river sections fall within Strahler types 7, 8, 9 and 10, with corresponding widths of 200–1,250 m or more. These water bodies are extremely open, and several deeper channels are often present. Riverbanks consist of Willow forests but often levees and floodplain areas are often cultivated in grassland or arable land. Typically, such large river sections contain islands, often (former) levees of the main stream, which hold softwood forests. During summer, low water conditions give rise to extensive sandbanks and isolated hollows and pools within these rivers.

Fish communities in river sections tend to vary with altitude and river width. Wide sections of large rivers are often characterised by the 'Barbel Zone', which has a gentle gradient, moderate water flow and temperature, with a good oxygen content and mixed silt and gravel substrates. It is characterised by some 'upstream' species (see Streams/small rivers) plus Barbel (*Barbus barbus*), Roach, Rudd (*Scardinius erythrophthalmus*), Perch, Pike and Eel. These rivers then enter the 'Bream Zone', the true lowland zone, where the gradient is very gentle and the water slow moving. Although oxygen content is usually good, temperature is more variable than in other zones and the substrate is

River Danube, one of Europe's largest river systems, Serbia. Photo courtesy of Daliborka Stankovic.

often silty and the water clarity low. Few upland species can survive here and only a few upstream species (Roach, Rudd, Perch, Pike) inhabit this zone that is also characterised by Bream, Tench (*Tinca tinca*) and Carp (*Cyprinis carpio*).

Impounded river sections of this size resemble medium-sized lakes, and sometimes have similar fish communities to these habitats. The dams, weirs and sluices associated with impoundment often hamper the movements of riverine fish. In winter, fish tend to concentrate in the deeper river sections, or migrate downstream. If spring flooding occurs, important habitat for spawning and nursery areas for juvenile fish are created in temporary riparian lakes and pools. Large rivers are often used as navigation routes for shipping and the course of the river has often been altered and the riverbed regularly deepened by dredging, such habitat modification usually has negative effects on local fish communities.

Streams, small rivers

River sections of the smaller categories fall within Strahler categories 2, 3, 4, 5 and 6, with corresponding widths of between 7 m (Strahler 2) and 125 m (Strahler 6). Riverbanks are mostly surrounded by trees, woodlots or forests but sometimes rivers also run through intensive agricultural land. If natural water regimes prevail, summer low flow levels lead to the presence of sand and pebble banks. The downstream (and hence wider) sections of rivers often become 'braided', the high sediment loads being deposited and the river forming a channel that consists of a network of smaller channels separated by little, and often temporary, islands called braid bars. These channels and braid bars are usually highly mobile and the river course can often change significantly during flood events. Channels move sideways because of their differential velocity, on the outside of a curve, deeper, fast-flowing water picks up sediment (usually gravel or larger stones) which is re-deposited in slow-moving water on the inside of a bend. Braided channels may flow within an area defined by relatively stable banks or may occupy an entire valley floor. These systems are often associated with numerous oxbow lakes and partially connected backwaters.

In upland areas, the smallest (Strahler 1) river sections occur in the uppermost fringes of catchment areas. Given their width of no more than a few meters, river sections of this size are normally not visited by Cormorants and they have therefore been excluded from further analysis here. In similar uplands, Strahler 2 and 3 category tributaries are often fast flowing waters with extensive pebble beds. These sections may or may not be surrounded by trees depending on altitude. The sub-alpine sections of such rivers rarely freeze due to the relatively high water flows.

Fish communities in small rivers and streams are diverse, depending on altitude and geographical position within Europe. As with all freshwaters, broad scale fish distribution is chiefly controlled by climatic, topographical and hydrological differences. Within Europe, as one moves westwards from the Danube, the freshwater fish fauna gradually becomes

Small rivers: Lowland (*left*) and sub-Alpine (*right*). Photos courtesy of INTERCAFE.

poorer in terms of species numbers. At the far west (the UK, Ireland and Norway) the native freshwater species are actually only those that became isolated there as sea levels rose after the last Ice Age or gained access from the sea during this period. Much of the current fish fauna is present entirely as a result of translocation by humans (e.g. Maitland & Campbell 1992). Overlaid on this for rivers, there is often a continuous increase in species richness (i.e. total number of species) with progression downstream. Thus, typical streams and small rivers start with a zone (the 'Trout Zone') characterised by steep gradients, fast flowing water and cool temperatures and holds Brown Trout, Atlantic Salmon, Bullhead (*Cottus gobio*) and Stone Loach (*Barbatula barbatula*). This is followed by the 'Grayling Zone' that tends to be slightly warmer

and can hold all the above species with the addition of Grayling, Minnow (*Phoxinus phoxinus*), Chub (*Squalius cephalus*) and Dace (*Leuciscus leuciscus*). Farther downstream, rivers can contain other zones with characteristic fish communities (described above).

Many coldwater species occur in small rivers and streams and water clarity here is generally high, due to low levels of algal production. Small streams and rivers in this habitat category can be disconnected from the downstream sections by dams (for water storage and the generation of hydro-electricity) and these barriers can cause serious problems for fish (particularly migratory species, including Salmonids) as they alter hydrological conditions and prevent the passage of fish. This can have severe effects on fish through physically restricting their access to upstream spawning sites and/or altering the substrate characteristics (through changes in water flow) and thus reducing the amount of suitable spawning area available to them.

Reservoirs, small lakes and sandpits

Water bodies in this habitat category are very often heavily influenced by hydrological management. The size of these waterbodies is highly variable, from a few hectares to 'small' lakes of some 10's of km^2 and to reservoirs that may be a few 100's of km^2. Not only is the water table set but the way that shorelines develop depends largely on management decision-making. Water depth varies according to the use of the waterbody, former gravel and sandpits being the deepest (10–30 m). Commonly, little vegetation grows around these relatively small standing waters and, in the case of deep waters, little or no aquatic vegetation grows. In reservoirs, fish populations are often isolated and small lakes and ponds are often stocked in order to provide quarry for recreational angling. Fish stocks in many of these waters are thus often enhanced or exist only because of the release of hatchery-reared fish. The most extreme type of waters are the so-called 'put-and-take' fisheries where fish of appropriate size are

Reservoir in Spain during a winter period of low water showing the remains of a former village. Photo courtesy of Mennobart van Eerden.

put into the water by fisheries managers for them to be taken out again (often very quickly) by anglers. Such fisheries may stock fish into their waters with a frequency of a few weeks or even days. The reproduction capacity of waters in this habitat category often depends on extra shelter or structural measures being provided to increase fish production.

The level of fish stocking depends, ultimately, on the type of stillwater. In the UK, recommended stocking density (biomass) for natural upland lakes is 100 kg/ha, for recently created lakes and gravel pits is 150 kg/ha, for mature gravel pits is 250 kg/ha, for mature lowland lakes is 350 kg/ha, and for rich farm ponds is 500 kg/ha.

A wide diversity of fish may be used in stocking, often dependent on the potential angling market. Thus many fisheries are stocked with Salmonid fish, very often the North American Rainbow Trout (*Oncorhynchus mykiss*) but also the native Brown Trout. These fish are stocked in a variety of sizes, often between 0.5–7.0 kg), and on capture are often removed by the anglers. Other fisheries can be stocked with a mixture of Cyprinid fishes, and traditionally, these fish are returned alive to the water after capture. At these fisheries, stocked fish may often include Roach, Bream, Crucian Carp (*Carassius carassius*), Rudd, and Tench. These fish are often stocked from around 8 cm but more commonly at 20–25 cm. Some fisheries specialise in large, so-called 'specimen' fish, of particular species, particularly Carp which are often stocked at around 1.5–2.0 kg and can grow to an average of about 16 kg (but up to 20 kg) within ten years.

Fishponds

Fishponds are artificially constructed water bodies, made by either damming off parts of a small river and/or by excavating new basins. Fishponds are often situated in areas that have relatively few natural water bodies and for many centuries people have used them to provide fish as an additional food source. Through intensification it has also been possible to export fish beyond purely local markets. Although some fishponds may be only a few hectares, many are much larger. For example, pond surface area in the Czech Republic ranges from about 140 ha to 7,500 ha. The existence of such large areas of shallow water in relatively dry habitat attracts various wildlife, especially in the more extensively operated systems, and so many fishponds are also associated with high biodiversity value. Similarly, many pond farms also have high historical, cultural and social value, as well as economic value through the production of fish.

The water clarity (and hence, underwater visibility) of fishponds is generally low because the bottom-dwelling fish species tend to stir-up the mud there. Furthermore, algal blooms often occur because of the absence of water plants and the relatively large inputs of nutrients.

Fish are often reared at very high densities in fishponds, depending on the intensity of fish farming. Production in fishponds is generally considerably higher than in similarly-sized natural waters, largely because of the additional food supplied to the fish. Standing stock in ponds in central Europe tends to vary between 200 kg/ha (almost natural) and 600 kg/ha (occasionally 1,000 kg/ha). However, in Israel there are some very intensive aquaculture systems (for Tilapia species and Carp), with stocking densities of more than 10,000 kg of fish per ha. Fish production is generally directed to one, or a few, core species and pond

The Nagli fish pond area in Latvia, reed burning in progress.
Photo courtesy of Karlis Millers.

farms in core central European areas tend to produce predominantly Carp, and to a much lesser extent Tench, Pike, Pikeperch and Wels (*Silurus glanis*). Other species of 'wild' fish enter these systems, and fish communities can be quite diverse but dominated by a few commercially produced species. In central Europe, fishponds are drained every second or third year and, during these periods of harvest, fish stocks may be particularly vulnerable to predators such as Cormorants and many other fish-eating birds and sometimes mammals, like Eurasian Otter (*Lutra lutra*), in the resulting shallow waters.

Most *sinensis* Cormorants in Europe breed in trees usually associated with wetlands such as willow (*Salix*), alder (*Alnus*) and birch (*Betula*). In some cases, tall old-growth forest is used such as these oaks (*Quercus*) in Braendegård, Denmark. Photo courtesy of Florian Möllers.

4.2 Cormorants and water systems

Cormorants feed almost exclusively on fish caught underwater whilst usually diving 2–5 m but occasionally up to 20 m or more. Whilst underwater visibility is very important for capturing fish, Cormorants tend to avoid both really clear water and extremely turbid water. Prey fish species are exceptionally diverse and can include shoaling species in the middle or upper parts of the water column and also demersal fish living close to, or on, the bottom. Birds may congregate in large flocks in order to prey on shoals of fish or make fish move up towards the clearer top layers of the water column where they can be more easily captured. Underwater vision is therefore considered a key parameter for describing the suitability of particular waters as feeding grounds for Cormorants.

In both winter and summer, Cormorants spend only part of their time in the water. Besides the foraging period that totals 1–4 hours per day on average, birds also aggregate at roosts to rest and preen (sometimes referred to as 'loafing') or at colonies to breed. Cormorants are so-called 'Central Place Foragers', that is they use their foraging area from a single point — the central place — to which they return (i.e. the roost or the breeding colony). As well as suitable foraging areas, Cormorants thus also require suitable nesting and roosting habitats. However, the species is remarkably flexible in its requirements for these sites, being able to breed in most relatively undisturbed areas — on cliffs, rocky coastal outcrops, trees and, where ground predators are absent, on the ground. Similarly, roost sites can be established on riverbanks or lakeshores in bushes, woods or single trees, or even on artificial structures. The distances flown to and from the roost or colony to the foraging grounds are generally 10–15 km in each direction but can range from less than 1km to over 40 km.

Birds spend about 3–4 months in colonies, from arrival, pair-forming and egg-laying to the time when young birds have fledged, left the nest and become independent but, if conditions are favourable, birds may stay longer at colonies or nearby, using the area as a night roost. Generally speaking, birds move to other post-breeding gatherings after the breeding period. In autumn, typically from mid-October onwards, birds perform longer migrations towards their wintering sites. This migration differs between individuals with some birds flying directly to their wintering site whilst others adopt a hopping strategy, visiting several locations en route. Some birds fly as far as northern Africa to spend the winter, but others may also be almost resident and move very limited distances throughout the year. In spring (from early March), a major northerly migration begins. However, many birds again show intermediate patterns with smaller movements between areas and some birds moving very little. As such, the Cormorant adopts the full array of avian migration strategies.

Subspecies: the *carbo* and *sinensis* races

As mentioned in chapter 2, there are two races of Cormorants in the area of 'Europe' considered here. The '*carbo*' or 'Atlantic' race has its main breeding distribution on the rocky coasts of Ireland, the UK, northwest France, Iceland and Norway, and also in Greenland and through the Russian Federation along the Barents Sea. The '*sinensis*' or 'Continental' race breeds inland across a wide area from France and Italy in the south to the Low Countries, Germany and Poland and north into the countries bordering the Baltic and is widespread throughout central and eastern Europe, extending into Belarus, Ukraine, Turkey, the Russian Federation and beyond. In winter *carbo* birds largely remain along the coasts but also partly move inland (e.g. in the UK) and migrate to the south (to Denmark, France, Spain and Portugal) where they mix with *sinensis* birds. Because of their habit of using exposed (often inaccessible) areas as breeding places, this part of the overall 'European' population cannot easily be monitored at the subspecies level and so there is less detailed geographical information on the *carbo* race compared with that available for *sinensis* birds.

5 CASE STUDIES FROM THE MAIN TYPES OF WATER SYSTEMS

INTERCAFE's Case Studies were identified so as to provide specific information about the relationship between Cormorants and their habitats. This chapter provides summary information about Cormorant habitat use, the general status and trends in fish populations, as well as the use that fisheries make of them for each location. Information collected during **INTERCAFE's** Case Study meetings (see Part Three of Marzano & Carss 2012) is complemented with information obtained from other sources including participant's knowledge of particular systems, the published literature, regular **INTERCAFE** meetings, and work undertaken at additional Work Group meetings. Table 5.1 gives an outline of Cases included here. This chapter focuses on the key ecological aspects whilst pertinent Cormorant-fisheries conflict issues are dealt with in chapter 10 (Europe-wide) and 11 (regional- and local-scales).

Table 5.1 INTERCAFE Case Study examples of Cormorant ecology in different water systems across Europe and Israel.

WG1 Case Study location	Section in chapter	Primary information source(s)	Habitat category
Gulf of Finland, Estonia & Finland	5.1	Regular INTERCAFE meeting and additional WG1 meeting	Open sea and coastal area
Po Delta, Italy	5.2	INTERCAFE Case Study	Estuary, complex river delta
Danube Delta, Romania	5.3	Additional WG1 meeting and expert knowledge exchange	Estuary, Large River and complex river delta
IJsselmeer, Netherlands	5.4	Expert knowledge exchange	Inland Sea
Vistula Lagoon, Poland	5.5	Regular INTERCAFE meeting	Inland Sea
Pre-Alpine streams, Slovenia & Austria	5.6	Regular INTERCAFE meeting, additional WG1 meeting and expert knowledge exchange	Small River and streams
South Bohemia, Czech Republic	5.7	Regular INTERCAFE meeting	Fish Pond, complex wetland
Saxony, Germany	5.8	Regular INTERCAFE meeting	Fish Pond, complex wetland
Hula Valley, Israel	5.9	INTERCAFE Case Study	Fish Pond, complex wetland

5.1 Gulf of Finland

Introduction

The Gulf of Finland is a large-scale coastal area in the northern European Baltic Sea, bordering Finland, Estonia and the Russian Federation. The salinity of the Baltic has been decreasing since the last century and the sea is becoming brackish and slowly being transformed into a fresh water systems. This is generally considered to be due to climate change with increased rain (fresh) water inflow from the surrounding river systems, and increasingly irregular inundations of sea water from the western approaches to the Baltic. The area is isolated from ocean influence so there is almost no tide. In spring and early summer, clear waters still dominate the coastal areas in the Gulf of Finland. In June 2007 Secchi depths (a measure of water clarity) recorded at Finnish coastal sites varied between 2.5–4 m (van Eerden *et al*. 2007). Nutrient loads to the Baltic Sea have increased since the early 20th century. Total nitrogen load has increased by a factor of 4 and phosphorus load by a factor of 8. The internal loading of phosphorus is an especially serious problem, and will continue to be so in the future, even though there has been some decrease in the external nutrient loads in the 1990s. Increased nutrient levels have caused intensified algae blooms, decreased water clarity and reduced oxygen conditions in the deeper areas of the Baltic.

The productivity of the Baltic Sea is based on the quantity of available nutrients entering it and nutrient concentrations here have increased considerably, especially because of the strong increase in human populations during the last century. Blue green algae (*Cyanobacteria*) now dominate the system in summer. The water residence time in the Baltic is around 20 years and the increased nutrient inputs have thus changed the Baltic considerably. Primary production is limited by both P (phosphate) and N (nitrogen). Blue-green algae are able to fix molecular nitrogen from the air and use the available phosphorus for growth. As both nutrients are limiting productivity, the additions of either will therefore increase biological production. Phosphorus levels in the Baltic remain high due to input to the water column from the benthic (bottom) substrates under low oxygen conditions. The only way to decrease phosphorus availability would thus be to decrease the amount of sedimentation of organic material, and as a consequence, enhance oxygen conditions on the sea bottom. In the Baltic, sedimentation of organic matter mainly arises from the spring production of green algae, which is nitrogen limited. There is thus the danger of a vicious circle in which the nitrogen-based spring bloom increases the phosphorus input in the water phase from the sediment. This, in turn, intensifies the growth of nitrogen-fixating *Cyanobacteria* speeding up the nitrogen accumulation of the water mass, thus enabling an increased spring production of plankton (Harri Kuosa pers. comm., Tvärminne Zoological Station, Hanko).

Fish communities

The water quality changes described above, among others, have both direct and indirect effects on fish communities in the Baltic. Total fish catches here have increased tenfold since the early 20th century. There are two reasons for this: (1) open sea fishing has intensified, and (2) fish production has increased, being correlated with nutrient enrichment leading to the state of eutrophication (Meri Härmä: Finnish Game and Fisheries Research Institute).

The pelagic fish community in the Baltic Sea (those fish species that live in the water column as opposed to close to the bottom) is dominated by four species: Baltic Herring (*Clupea harengus membras*), Sprat (*Sprattus sprattus*), Cod (*Gadus morhua*) and the anadromous (i.e. breeds in freshwater, matures in the sea) Atlantic salmon (*Salmo salar*). There was a regime shift from a Herring- and Cod-dominated community to one dominanted by Sprat during the 1990s. There were several reasons for this. Cod stocks collapsed due to over-fishing and deteriorating oxygen conditions

Baltic Sea coast and rocky islets off the Hanko Peninsula, Finland.
Photo courtesy of INTERCAFE.

in their spawning areas. Changes in salinity conditions have also affected the food supply of Herring and Sprat.

Nowadays freshwater fish species dominate in the northern Baltic Sea. Roach (*Rutilus rutilus*) is now the most abundant species in the northern coast of the Gulf of Finland and in the Archipelago Sea. During the 1990s, the species spread out even to the outer archipelago. The abundance of other Cyprinids, like Bream (*Abramis brama*) and Silver Bream (*Blicca bjoerkna*) has also increased. Eutrophication and climate change (increased amount of nutrients and more rainfall, and hence freshwater run-off, decreasing the salinity of waters in the region) have resulted in improved reproductive conditions for Cyprinids in the innermost

Extensive coastal lagoon system, Po Delta, Italy. Photo courtesy of INTERCAFE.

archipelago and are the main reasons for the recent increase in Cyprinid abundance. Some other species like Pikeperch (*Sander lucioperca*) have also benefited from changes in the coastal environment. It is expected that in the next 100 years climate change will probably further decrease the salinity of the Baltic Sea (e.g. by increased rainfall in winter leading to increased run-off) and the decreasing salinity in spring will most likely benefit the reproduction conditions of Roach.

The general situation in the study area at present is one of low fish stocks or the absence of large predatory fish. Stocks of large Cod, Pikeperch, Eel, Atlantic Salmon and migratory Brown Trout, so-called Sea Trout (to name but some key species) have greatly decreased in recent decades (1980–1995). The decreasing salinity, combined with increased inflow of nutrients and a high fishing effort by the commercial fishery has lead to marked changes in fish composition. It is therefore highly likely that the absence of large predatory fish has led to an increase of small prey fish. It is well known that species like Eelpout (*Zoarces viviparus*), Butterfish (*Pholis gunnellus*) and Gobies (Gobidae) formed important prey for Cod in the past but these species (and possibly others) may now be experiencing considerably reduced predation pressure from piscivorous (fish-eating) fish species. The recent expansion of Cormorants into Baltic Sea waters may thus be facilitated by the low number of large predatory fish species.

Role of Cormorants

The recent expansion of Cormorants in northern Europe is particularly evident in the eastern Baltic area, the Gulf of Finland and the Gulf of Bothnia. Generally speaking, fewer commercial fish are being caught here, whereas the Cormorant population is expanding greatly, a situation of great concern to many local people (see also Marzano & Carss, 2012). However, on the Finish side, coastal fisheries largely stopped around 1960, well before the arrival of Cormorants. Estonian and Finnish governments have implemented European environmental legislation by establishing nature reserves and through the proper implementation of nature management and inventory tasks. The changing society and the current greater role of tourism is a common development in the region (van Eerden *et al*. 2007).

5.2 Po Delta

Introduction

The Po Delta (NE Italy) can be defined as the 80 km of coastal belt from the River Adige and the wetlands north of the town of Ravenna, including both the present (Veneto region) and the historical river delta (Emilia-Romagna region). Typically for large estuarine areas, the Po Delta is a complex ecological system including a mosaic of more than 38,000 ha of highly productive eutrophic wetlands. Shallow coastal sea bays (6,200 ha), brackish lagoons (25,000 ha), freshwater marshes (800 ha) and a complex web of canals and river branches lie in a continuum with the lagoon of Venice and Caorle (57,000 ha) and wetlands of the Gulf of Trieste (30,000 ha). The vertebrate fauna comprises some 374 species, plus more than 300 bird species reported during the last few decades. Most of the Delta is protected as regional parks and included in the Natura 2000 network as SPA/SCI, while many wetlands are on the Ramsar list of protected sites for the conservation and wise use of wetlands and their resources.

Fish communities

The fish fauna of the Po Delta comprises over 60 species including freshwater, brackish water and coastal sea species (Gandolfi *et al*. 1985). Fishes adapted to eutrophic waters with low oxygen content dominate in riverine habitats and freshwater marshes. Here the most abundant species are Cyprinids, such as Crucian carp (*Carassius carassius*), Ruffe (*Gymnocephalus cernuus*) and Common Carp (*Cyprinus carpio*), but several exotic species are common (e.g. Wels (*Silurus glanis*), Black Bullhead (*Ameiurus melas*), Mosquito Fish (*Gambusia affinis*) and play an important role in the fish community. Estuarine and brackish waters account over 30 species. Among those, five species of Grey Mullet (Mugilidae), Sea Bream (*Sparus aurata*), Sea Bass (*Dicentrarchus labrax)*, Eel (*Anguilla anguilla*) and Big-scale Sand Smelt (*Atherina boyeri*) are the fishes of highest commercial interest.

Role of Cormorants

Since the early 1980s, Cormorant numbers have increased considerably in the Po Delta so that the delta can now be considered a 'honey pot' area for the species. Recoveries of ringed birds have shown that Cormorants visiting the Po Delta originate mainly from the Baltic countries and The Netherlands. Nowadays, about 6,500 Cormorants, with occasional peaks up to 10,000 individuals, regularly winter in the whole Delta, whilst about 1,000 pairs breed in the largest Italian colony located in the Southern Delta. Stomach and pellet analysis has shown that Cormorants here prey on a diverse range of fish species. However, there is large variation in the proportions of different fish prey taken according to both season and foraging site. Mullets and Big-scale Sand Smelt dominate by number and biomass during autumn, while Gobies (Black Goby *Gobius niger*, Grass Goby *Zosterisessor ophiocephalus*) and Flounder (*Platichthys flesus*) are taken especially in spring (Volponi & Callegarini 1997). Predation on the most valuable commercial species (Eel, Sea Bass and Sea Bream) occurs mainly in lagoons used for 'vallicoltura', where they may cause important economic loss (Volponi & Rossi 1995).

5.3 Danube Delta (Romania, Ukraine)

Introduction

This is one of the largest river deltas in Europe (5,800 km^2). The area consists of extended areas of shallow (1.5 m) eutrophic and partially mesotrophic waters. This huge area has peat, clay and sandy areas in combination with a wide array of water bodies (large and small lakes, pools, backwaters, inundated meadows and brackish transitional waters including lagoons).

Large parts of the water systems are turbid (with visibility of around 0.75 m or less), but some lakes and isolated backwaters maintain a clear water state for longer periods, often into the summer. During high water flows a large sediment load is typical for these waters and it can extend more than 10 km into the Black Sea. Water plants are an important component of the system if nutrient conditions are modest and shore-based vegetation comprises meadows, marshes, and forests but may also consist of sandy levees with little, or no, vegetation at all. The latter is typical for the areas close to the Black Sea.

Since the construction (in 1972 and 1984) of the Iron Gates dams and associated power stations in the Danube (near the Romanian-Serbian border), water movements in the system tend to be less than before. Lack of dredging in recent years has resulted in increased siltation and water 'stagnation' in many places. Nevertheless, floods still occur in late spring and large parts of the delta remain subject to fluctuating water levels. Shipping is mainly through the deeper canals, but fishing boats may enter many of the different water bodies. The area is of the highest international importance in relation to its biodiversity value, the size of the area and the sheer diversity of habitat types supporting a wealth of species. For example, with respect to fish-eating birds all European herons and egrets nest in the area, together with two species of pelican and both Cormorant and Pygmy Cormorant (*P. pygmaeus*). The latter species has its European stronghold in this single area (see Platteeuw *et al*. 2004).

Fish communities

The Danube Delta waters support up to 125 fish species. Cyprinids and Gobiids are most abundant (overall biomass is high and can be around 250 kg/ha). Many species also migrate through the area, including the Pontic Shad (*Allosa pontica*, see Navodaru, 2001) and several species of Sturgeons (Acipenseridae). Fish species composition differs with respect to the different water bodies. Backwaters and lakes further from the main stream comprise less eutrophicated and thus more waterplant-rich systems. Brackish waters occur at the coastal areas of the Delta. The huge Lake Razelm (45,000 ha) is turbid and comprises entirely of freshwater. Here, Pikeperch is the dominant predatory fish, whereas in the more clear water areas of the Delta the Pike (*Esox lucius*) has this role.

Role of Cormorants

The Danube Delta is home to about 16,000 breeding pairs of Cormorants, and up to 40,000 birds may be present in the area in total. Colonies are dispersed over the area, but mainly occur in the inner part of the delta. Birds fly to the larger lakes to forage, often in combination with pelicans. The main channels of the river are used as foraging sites in early spring and again in late autumn. Coastal lagoons and lakes (Sinoie, Razelm) form typical post-breeding habitat and sometimes excursions range into the shallow parts of the Black Sea. Post-breeding concentrations typically form along the shores of the Black Sea. During frost periods most Cormorants leave the area, but in mild winters several thousands stay behind, near the mouth of the main channels (Chilia, Sulina, and Sf Gheorghe). Cormorants prey on a variety of species, much depending on season and foraging-site location. The large scale of the delta complex and the occurrence of many different habitat types imply the buffering of individual water bodies with regard to predation pressure. Moreover, the occurrence of natural protection for fish (water plants, debris, overhanging trees, deep channels and turbid waters) is likely to limit the effect that birds might have on the ecosystem.

5.4 Lake IJsselmeer, The Netherlands

Introduction

Lake IJsselmeer is a former inland sea situated in the Netherlands. After closing it with a large dam in 1932 it became a fresh water lake. After 1932, large parts (around 2,000 km^2) were reclaimed and cultivated as polders. The remaining part was split in two in 1975 forming the present Lake Markermeer (700 km^2) and the IJsselmeer (1,150 km^2). These fresh, water lakes are shallow (4–6 m depth) and stagnant. The water is turbid with visibility depths of less than 1 m (often only 0.2–0.5 m). The water is eutrophic with a strong tendency of lowered nutrient loads of N and P since 1980. The lakes are heavily used by humans for transport, sand extraction, spoil deposition and recreational boating (both motorised and sailing craft) and they also support commercial fisheries. The lakes are both Ramsar sites protected for the conservation and wise use of wetlands and their resources and were included in the Natura 2000 network (SPA/SCI) in 2003.

Fish communities

Altogether, 40 species of fish inhabit the system (Lammens *et al*. 2007). Initially the lakes had a semi-natural fish community with good stocks of predatory fish species like Pikeperch and Perch. Eel was also a common fish species in the early 1980s. Furthermore the lakes held an important population of Smelt (*Osmerus eperlanus*), situated at the southwesterly edge of its distribution range in North West Europe. These four species form the greater part of the target of the commercial fishery. Another important part of the fish community comprises Roach and large Bream. Due to the heavy fishing pressure on Pikeperch and Perch, stocks of these species have decreased. Recently, due to selective fishing for Bream and Roach, the smaller Ruffe has experienced reduced competition and has increased substantially to form the biggest part of the fish stock nowadays. Cormorants in the area feed largely on Ruffe, recently recorded at up to 70% of their diet (van Eerden & van Rijn in prep.).

Role of Cormorants

Cormorants have been protected in the Netherlands since 1965. This country, with a significant breeding population, was the first in Western Europe to ban interference in colonies. At that time, the species was rare due to poor water quality (the effect of pesticides), drainage of wetlands and continual persecution of the birds. However, protection and enhanced water quality caused an increase of the Dutch population in the 1970s and 1980s. Numerically, growth started in the IJsselmeer area and levelled off in the 1990s. Since 1995, some 10–12,000 pairs of Cormorants have bred annually in the Lake IJsselmeer system (55–67% of the total Dutch population, in seven colonies). Although in more colonies, this is fewer birds than at the beginning of the 1990s when the number reached more than 15,000 breeding pairs under temporary favourable circumstances. A natural stabilisation of Cormorant numbers took place after a dramatic decrease in 1994 and for almost two decades the total population has remained stable. As this natural stabilisation suggests, the maximum level of exploitation of the area has probably been reached. Furthermore, production of young in the colonies is now at a low level in most years, often being less than one young fledged per nest (van Rijn & van Eerden 2002). As well as the breeding population, there are also staging birds in winter. The wintering numbers were low in the 1980s and 1990s with only several hundred birds at most, but they have increased in the last 10 years up to 5–8,000 birds are present in mid-winter.

5.5 The Vistula Lagoon, Baltic Sea coast, Poland

Introduction

The Vistula Lagoon is a large shallow eutrophic water body located on the southern shore of the Baltic Sea. The Lagoon is about 80 km long and 6–10 km wide, and stretches over 838 km^2 of which 328 km^2 is situated in Poland and the remainder in the Russian Federation (Kaliningrad region). The Lagoon is separated from the Gulf of Gdansk by a long sand spit, the Mierzeja Wislana and the only connection with open sea is through the Baltijsk Channel. The average depth in the Polish part of the Lagoon is 2.4 m and the maximum is 4.4m. Wind direction and strength are the key factors driving the lagoon environment. Influxes of seawater from the Baltic can cause considerable fluctuations in the water level, sometimes exceeding 1 m in 24 hours, and also lead to changes in salinity. This normally ranges from 0.5% in the SW area to 3% in the centre, but during storm surges may increase to 4% and 6%, respectively. Waves, which can reach a height of 1.2 m, cause the quick mixing of the water in the Lagoon. The influx of fresh water from the River Nogat, other tributaries of the Vistula and the rivers flowing down from the Elblag Heights, have negligible effects on water levels and salinity.

Fish communities

The fish community of this eutrophic lagoon is dominated by Cyprinid fishes, mainly Roach and Bream. Ruffe, a commercial species here, is also abundant. Most important commercial species fish are Pikeperch, Atlantic Salmon, Sea Trout (*Salmo trutta*), and Eel. In the most recent years, the Round Goby (*Neogobius melanostomus*) has become one of the most abundant species both in the fish community and the diet of Cormorants. This bottom-dwelling, aggressive fish arrived from the Black and Caspian Sea region and, as an invasive species, has rapidly colonised the lagoon.

Role of Cormorants

Cormorants inhabit the Vistula Lagoon mainly during the breeding period (April to July) and only a few individuals remain during winter. Cormorants often breed in mixed colonies with Grey Herons (*Ardea cinerea*) in the dry Pine forest of Kąty Rybackie, on the Vistula Spit. The colony here has increased significantly during the last few decades from over 3,500 pairs in 1990 (Przybył 1994) to almost 6,000 pairs in 1996, becoming (in 2004–2006) the largest European Cormorant colony with 11,500 pairs. Studies carried out on regurgitations and pellets since the mid-1990s have shown that Cormorants feed mostly on Ruffe (58–75% by number), Roach (5–12%) and Round Goby (Martyniak *et al*. 1997, 2003; Stempniewicz *et al*. 2003a, b). Pikeperch and Eel represented 1.2% and 2.9% respectively, of Cormorant prey during the breeding season. Cormorants feed in both in the Lagoon and also at sea along the Vistula spit.

Small-scale commercial fishery operating in the Vistula Lagoon, Poland. Photo courtesy of INTERCAFE.

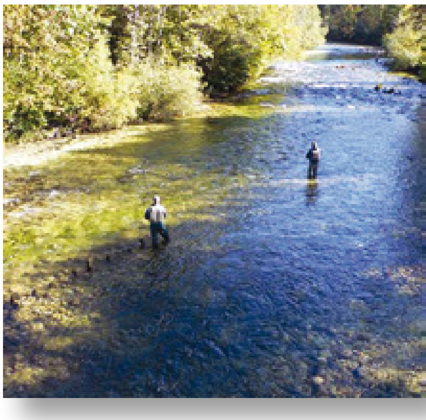
5.6 Slovenian & Austrian pre-Alpine rivers and streams

Introduction

The fish populations of most Austrian rivers have been carefully investigated whilst in Slovenia, the Sava and Sava Bohinjka are well-studied pre-Alpine river sections. Water quality is extremely good as effluents from settlements generally do not occur. In these waters, those stretches in the 'Barbel-zone' (see section 4.1) are particularly rich in species. These river stretches are slow-flowing with increasing amounts of silt compared to those further upstream, and have considerable aquatic vegetation cover. Stretches of fast-flowing water occur further upstream and these are typically inhabited by salmonids like Brown Trout (*Salmo trutta*) and also Grayling (*Thymallus thymallus*). These waters are generally characterised by high fish species diversity that is also reflected in the diet of Cormorants. Construction of hydro-dams has disconnected the migratory pathways for fishes and has also impacted the discharge patterns, and locally the flow speeds, of rivers.

Fish communities

Given the special mountainous river conditions that prevail in the lower Alpine range, in both Slovenia and Austria, the fish community is rather unique and differs considerably from many other mountainous parts in Europe. Also for the lower parts these river sections hold fish populations that are diverse and comprise many more species than elsewhere in north-west Europe. In Slovenia for instance, over 90 species of fish occur and many are endemic to the country or to a relatively confined



Typical small sub-Alpine river, Slovenia. Photo courtesy of INTERCAFE.

area in the Balkan countries. In the upstream parts the Salmonids represent a significant and, from the perspective of biological diversity, a highly valuable part of the aquatic fauna and these values are internationally recognised and protected under the EC Habitat Directive. For example, the Marbled Trout (*Salmo marmoratus*) is now considered a separate species and much effort has been directed to the reconstruction of the original genotype. In Slovenia, a genetic breeding programme runs parallel with measures to reduce the occurrence of foreign species/races of fishes and an awareness programme amongst anglers to develop a framework for sustainable recreational fishing.

Role of Cormorants

In the 1970s, Cormorants were rare visitors to Slovenia and they were still uncommon in the early-1980s but the first flocks appeared in 1984. It was estimated that in 1993–1994 about 1,000 Cormorants wintered on large lowland rivers in Slovenia, and a few thousand have done so in more recent years. On the basis of ringed Cormorants, these birds breed in Denmark, Sweden, Poland, Estonia, The Netherlands, Germany and Croatia (Govedič 2001).

As in the whole of Slovenia, there are no Cormorant breeding colonies in the Soča valley and bird presence is limited to relatively small numbers during winter and migration periods. There was a general agreement on the need for basic information on Cormorant ecology from a wide geographical range to be able to elaborate a local management policy for the Cormorant problem. So far, the situation in (westernmost Alpine) Slovenia has still not produced a lot of Cormorant damage cases.

The diet of Cormorants wintering on the Sava River between Ljubljana and Zagorje in the winter of 1998–1999 (Sava River and its tributary, Ljubljanica) consisted of 23 fish species, by far more than is regularly found elsewehere (4–10 species): (Brown Trout, Rainbow Trout (*Oncorhynchus mykiss*), Huchen (*Hucho hucho*), Grayling, Chub (*Squalius cephalus*), Nase (*Chondrostoma nasus*), Danube Roach (*Rutilus pigus*), Roach, Blageon/Soufie (*Telestes souffia*), Prussian/Gibel Carp (*Carrassius gibelio/C. auratus*), Barbel (*Barbus barbus*), Bream, Pike, Perch, Rudd (*Scardinius erythrophthalmus*), Carp, Tench, Schneider (*Alburnoides bipunctatus*), Zährte (*Vimba vimba*), Streber (*Zingel streber*), Bullhead (*Cottus gobio*), Burbot (*Lota lota*) and Weather Fish (*Misgurnus fossilis*). In the river Ljubljanica, 27 fish species were documented, including 8 not recorded in the Sava; Crucian Carp (*Carassius carassius*), Gudgeon (*Gobio gobio*), Minnow (*Phoxinus phoxinus*), the Cyprinid *Barbus petenyi*, Pikeperch, Wels (*Siluris* *glanis*), Bleak (*Alburnus alburnus*) and Golden Loach (*Cobitis aurata*) (see Govedič *et al*. 2002).

Cormorants from the night roost at Hotic consumed between 16,071 and 32,143 kg of fish or between 44.8 and 89.6 kg/hectare in winter (1998/99). From the same section of water 8,812 kg of fish (31.6 kg/ha) was taken by anglers in 1998. However, since the productivity of this stretch of river was not known it was impossible to evaluate the effect of Cormorant predation on fish stocks there. Among 473 pellets, 70 % contained the remains of fish but they also contained Nematode worms and tapeworms, the remains of caddisflies, snails (largely remains of diet of fish species eaten) and a single frog. In individual pellets, the remains of between 1–69 fish (median = 2, average = 3.9) were found: most (93.6%) contained the remains of up to 10 fish. Altogether, the remains of 1,279 fish were found. The total weight of these fish was estimated at 57 kg. The diet consisted of 12 fish species: Brown Trout, Grayling, Chub, Nase, Danube Roach, Roach, Barbel, Bream, Bleak, Pike, Perch, and Ruffe. Most of the diet consisted of cyprinids (88% by number, 90% by biomass) although Grayling and Brown Trout represented 6% by number and 4% by mass and Pike, Perch and Ruffe represented 7% by number and 4% by mass. Among the Cyprinids, Chub (16% by number and 39% by mass) and Nase (4% by number and 16% by mass) were most common. The proportion of unidentified Cyprinids was 57% by number and 28% by mass.

Prey size ranged from 23 to 345 mm. The most frequent length class was 70–170 mm (50% by number and 19% by mass), but large individuals (>170 mm) were common (25% by number and 80% by mass) in the diet of Cormorants. The respective numbers of Cyprinids, Percids, and Salmonids varied significantly between months while the number of specimens did not. It was concluded that the differences in fish species caught by Cormorants in the study area depended on random detection of a particular fish species and was not the result of selective hunting. Chub and Nase are shoaling fishes and are probably more easily detected by Cormorants than the non-shoaling species.

5.7 South Bohemia, Czech Republic

Introduction

The Czech Republic includes several water systems types that are used by anglers or by commercial fisheries. Large rivers, small rivers and reservoirs are mostly stocked with fish species to be used for angling. Large- and medium-sized fishponds, which have existed since the Middle Ages, are traditionally used by Carp (Cyprinus carpio) farmers. For a long period, man has managed the water resources in this region by increasing the amount of still waters. As in Germany, parts of France and further in Eastern Europe, these artificial lakes and ponds are used for fish farming. Nowadays, about 20 million kg of fish are produced annually in the Czech Republic, of which about 420 kg per hectare come from the south Bohemian Carp region. Since 1995 this production has slowly increased. Production is divided about equally between two kinds of pond farms, extensive 'natural' ones and more intensive systems where the fish are fed with wheat and manure is used as a fertiliser. There are no commercial fisheries on Czech reservoirs, except for a very poor Eel fishery. In South Bohemia the majority of the water surface area (about 85%) consists of isolated ponds and lakes, the remaining surface area is made up of rivers. This compares to the Czech Republic as a whole where rivers and lakes each comprise about a third of the water surface area, the remainder comprising lakes and ponds connected to larger rivers, often with dams.

Fish communities

At a European scale, the Czech Republic is at the centre of the major European watersheds, those running towards the Black Sea and those to the Baltic-North Sea. Rivers can be categorised as (1) small/upstream or (2) large/downstream. In both types, the fish communities are rather diverse, with some 25–30 species. Small rivers are dominated by Brown Trout, Rainbow Trout and Grayling. More downstream rivers are dominated by Roach and Chub; the remaining species being a considerably less significant part of the fish stock. Pike occurs everywhere but in very low numbers (no more than 2% of stock). Wels is present in reservoirs and lowland rivers, again in very low numbers.

Table 5.2 shows the fish species and the approximate productivity for different Czech water bodies on an annual basis. The lowest production occurs in small running waters where Trout and Grayling occur, with an annual production of some

Table 5.2 Simplified overview of the major fish species and scale of fish production in different water systems in the Czech Republic.

Water body type	Main fish species	Annual production (kg/ha)
Small river	Trout, Grayling	50
Large river	Roach, Chub	300
Reservoir	Bream, Roach, Bleak, Perch	250
Pond	Carp (Grass Carp, Silver Carp)	500 (but up to 1,000)

Table 5.3 Estimated percentage share of different water bodies in Czech Republic and estimated percentage share of use by Cormorants, and absolute estimated number of birds.

Water body type	% share of total water	% share of birds (winter)	% share of birds (summer)	Estimated bird numbers (winter)	Estimated bird numbers (summer)
River	30	80	-	8,000	-
Pond	30	5	100	500	1,000
Reservoir	30	15	-	1,500	-

50kg/ha. In both reservoirs and large river sections, fish production is higher (250 and 300kg/ha, respectively) and the fish species also differ. In reservoirs, Bream, Roach, Bleak and Perch are usually the dominant species, whereas Roach and Chub predominate in larger river sections. The highest annual fish production is recorded in ponds where an average of 500kg/ha is fairly representative for large areas, but occasionally the more intensively farmed areas may yield up to 1,000 kg/ha/year. In contrast to the other (more natural) systems, Carp is by far the commonest species held in fishponds.

Role of Cormorants

Management measures have resulted in a comparatively low number of breeding Cormorants in the Czech Republic. Cormorants are allowed to breed in a few strictly protected nature reserves. Wintering Cormorants are present in increasing numbers and these birds have most interactions with fisheries' interests. However, most fishponds freeze in winter and some are left drained after the fish are harvested and so these are not used by wintering Cormorants. Otters form a biologically comparable predator, in terms of the amounts of fish taken in the region.

Extensive naturalised Carp pond farm system, South Bohemia, Czech Republic. Photo courtesy of INTERCAFE.

Table 5.3 illustrates how the water surface area of the Czech Republic is distributed and how Cormorant numbers are distributed between waters, both in winter and summer. Wintering numbers of Cormorants are higher than those in summer and wintering birds appear to make preferential use of the river systems. In summer, birds mainly forage specifically in pond areas where they also breed.

5.8 Upper Lusatia, Saxony, Germany

Introduction

The Upper Lusatia region covers about 950 km^2 and the area is the centre of Carp (*Cyprinus carpio*) production in Saxony, holding a large concentration of fish ponds — many of which are intensively managed. Local Carp production is a 500-years-old tradition and considered a good example of sustainable fish production. Water for the fish ponds is sourced from impounded river sections. Ponds range in size from several hectares up to over 100 ha each; they are about 1.5 m deep, extremely turbid and stocked with abundant small fish. Ponds look semi-natural, and are surrounded by trees and bush growth, resulting in a semi-closed landscape. Sparsely inhabited and large forested areas surround many of these water bodies. Smaller or wider stretches of Reed, Bulrush or other macrophytes border the small lakes and, in some places, the water table is maintained artificially. At the time of fish harvest, the pond system is

Dense aquatic vegetation on the banks of extensive, naturalised Carp pond farm system, Saxony.
Photo courtesy of INTERCAFE.

drained and fish are collected from the deepest part of the basin.

Larger water bodies in the area include reservoirs, river sections and recently developed water bodies resulting from restoration activities in former open cast coal mining areas. The system is also considered important for biodiversity. Former open-cast coal mines in Upper Lusatia are being converted into artificial lakes, sometimes relatively large ones, by stopping the active drainage of water from the mines and by pumping water directly from the River Spree system. Fish are thus transferred from the river Spree into the artificial lake as river water is being used to fill it. One reservoir (Talsperre Quitzdorf) was created by a dam installed on a tributary of the River Spree on a flood plain only 3 m deep. Its main function is to supply water for industry but also for aquaculture and to provide flood protection. The reservoir is also used for recreation, angling and nature conservation. Water is now being taken from the reservoir to maintain the level of the river Spree.

Fish communities

The total production of Carp in the area is about 900 tonnes, for which some 3,000 tonnes of wheat are supplied annually as food for the fish. Besides harvestable Carp (3-year old fish), a further 800 tonnes of fry (young-of-the-year,

0+ fish) and young (1+ group) fish are produced each year. Other, more recently introduced species include Catfish, Grass Carp and Silver Carp, but Carp remains the main species under cultivation. Typical lowland freshwater species like Bream, Ide (*Leuciscus idus*), Roach, Perch, Tench and Rudd occur in the small flowing rivers and unmanaged ponds and lakes.

Role of Cormorants

The Cormorants in this area are migratory, exploiting the water bodies from about five main roosts. Cormorants use the area during migration as a stopover site. Sometimes they have attempted to establish nests but these have been destroyed. In winter when waters are often frozen, the birds leave the area. Possible impact of Cormorants on fish stocks has been little studied so far and there are few data on the diet of birds in the region.

5.9 Hula Valley and Lake Kinneret (Sea of Galilee), Israel

Introduction

The Hula Valley is a large area with a complex of natural habitats (Lake Agmon area), the large Lake Kinneret (Sea of Galilee, 166 km^2), scattered pond farms and a few reservoirs. One such is the Anan Reservoir with an area of about 40 ha and depth of up to 11 m. It contains 'second hand' water (from the surrounding area) that is used in the lowlands and then pumped some 800 m into the hills. The Lake Agmon area was the first wetland site to be reinstated in Israel. In 1992, part of the Hula Valley was re-flooded after earlier drainage of the area and the Lake Agmon Nature Reserve was formed. In the rest of the Valley there are around 100 km of canals, which create a unique wetland system. All agriculture has changed and new products are produced, including peanuts.

Fish communities

Fish farmers in the Hula Valley cultivate mostly Carp but also Silver Carp, Chinese Carp and Mullets. The Reservoir produces over 400 kg/ha/year, mostly Carp but also Grey Mullet and Silver Carp. Intensive fish farming complexes are located south of Sea of Galilee, with an average production of 10,000 kg of fish/ha/year. These farms hold Carp, Tilapia and other species. Intensive Cormorant shooting is undertaken throughout daytime in order to protect the area from visiting birds.

Role of Cormorants

Cormorants winter in the Hula Valley and at the Sea of Galilee. Wintering birds in Israel are part of a flyway originating from a large breeding population in the Ukrainian river deltas of the

Fish pond area in the Hula Valley, Israel a former natural wetland area. Photo courtesy of Stef van Rijn.

northern Black Sea. When the Hula Valley project was started, there were 8–9,000 Cormorants in the Hula Reserve — winter visitors between November and mid-March. About 1,000 of these birds fed on surrounding aquaculture ponds each day. The flight time from the roost in the Reserve to the nearest ponds is about 30 seconds, and birds would feed at the ponds for about 30 minutes at a time. Other birds moved out to other fishponds, and around half of the birds flew the 25–30 km south to Galilee. By January, around 90% of the birds were making foraging trips to the Sea of Galilee, implying that changes had occurred in the availability of fish in ponds closer to the Reserve during the course of the winter.

Nowadays about 1,500 Cormorants winter in the Hula Reserve and only about 200 appear to forage in the surrounding ponds. Some birds make daily foraging trips into Lebanon and some go into the Golan Heights. Large roosts occur on the shoreline of the Sea of Galilee, where 12,000 Cormorants may regularly forage. At this large lake there appeared to be few, if any, conflicts with local fisheries interests perhaps due to the lake's very large size and/ or the relatively low underwater visibility offering a degree of 'protection' to the fish stocks there. Detailed studies with captive birds have shown many new facts with respects to underwater vision and fish detection (Strod *et al*. 2004). The protection of Cormorants in certain areas in combination with effective disturbance programmes in the most sensitive areas has greatly alleviated the problems with Cormorants. Similar routines with the aim of zoning the use of specific habitats/areas that 'conflicting species' are allowed to exploit have also been developed for Cranes (*Grus grus*) and White Pelicans (*Pelecanus onocrotalus*) (Shmueli *et al*. 2000, Gutman *et al*. 2001).

6 CORMORANTS ON A WIDER EUROPEAN SCALE

This overview presents the most recent information on the numbers and geographic distribution of Cormorants *Phalacrocorax carbo*. It is based on two pan-European censuses, carried out for wintering birds in January 2003 and for breeding birds in 2006. Cormorants show distinct patterns of occurrence and different populations use this vast area, which extends partly into the Russian Federation, Northern Africa, Turkey and the Middle East. Therefore, when discussing Cormorant numbers ‘in Europe’, it is important to define the precise geographical area under consideration. Also the period during the year is important with respect to the numbers and distribution of Cormorants.

6.1 Ecology, flyways and countries involved

In the western Palaearctic Europe, the Middle East and North Africa constitute the main area of distribution of two subspecies of the Cormorant: *sinensis* occurring mostly inland and along coasts of non-tidal waters and *carbo* breeding on rocky coasts in more exposed, marine habitat. The population and range of distribution extends from Europe into Asia as far East as China. ‘Europe’ can be broadly split into three regions, mainly according to the breeding distribution and migratory movements of Cormorants:

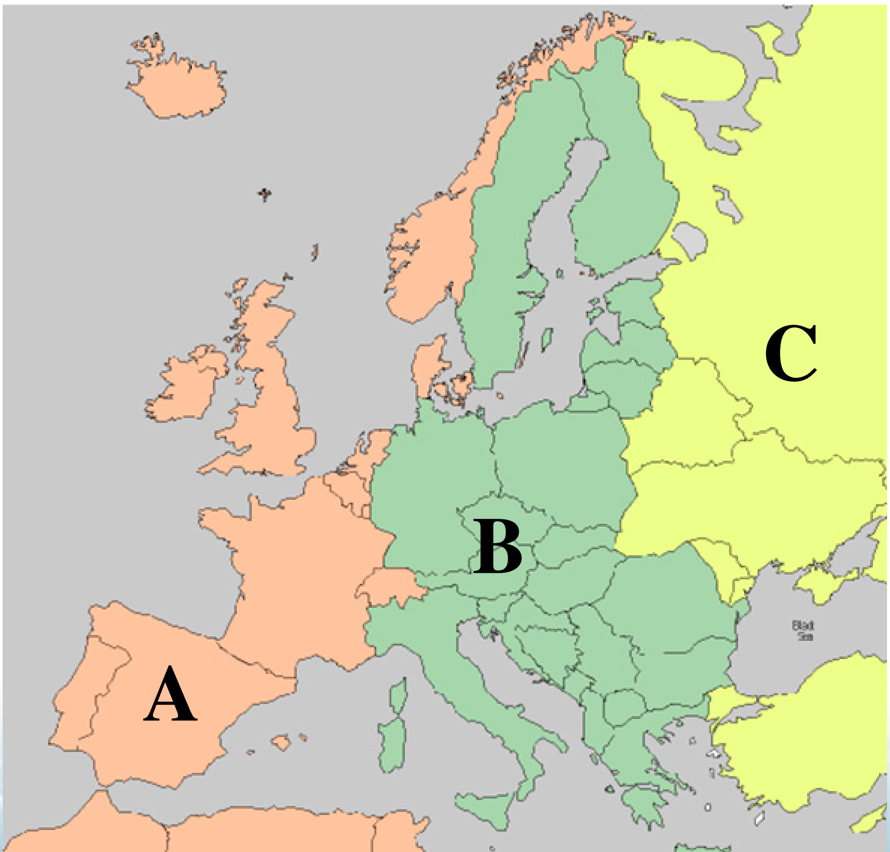


Figure 6.1 Map of Europe and beyond showing the major areas of occurrence of Cormorants (regions A, B and C).

A. **Atlantic-North Sea/western Mediterranean** population ranging from Norway, Denmark, UK, Ireland, Low Countries, France, into the western Mediterranean; this group includes the subspecies *carbo* which is largely confined to coastal marine waters in summer but can move some distance inland in winter.

B. **Baltic/central European** population ranging from Sweden, Finland, the Baltic countries, Poland, Germany, all the way south through central and eastern Europe (Danube countries) to the south including Italy and Libya.

C. **Black Sea/eastern Mediterranean** population ranging from Belarus, Ukraine, European Russia south to Turkey, Israel and Egypt and possibly Sudan.

These three regional groups should not to be considered as closed units operating independently but more as 'meta-populations' given the large geographical area they are operating in. A metapopulation consists of a group of spatially separated populations of the same species which interact at some level. The term metapopulation was coined by Richard Levins in 1970 to describe a model of population dynamics of insect pests in agricultural fields, but the idea has been most broadly applied to species in naturally or artificially fragmented habitats. In Levins' own words, it consists of 'a population of populations' (www.Wikipedia.org). Notice that both regions A and B have strong links in winter to countries outside the EU, whereas those birds in region C are largely confined to non-EU countries throughout the year.

6.2 Breeding numbers and distribution

Researchers are far less well informed about the Cormorant population in region C, a territory that includes Belarus, Ukraine, European Russia and Turkey, where some 87,880 breeding pairs were estimated (Table 6.1). In order to arrive at a realistic estimate of the number of birds in this region, estimates for average production of fledged young in three categories were used. These production estimates (from research undertaken in regions A and B) were derived from production levels in (i) old, long-established colonies (1.0 fledgling/nest), (ii) relatively new expanding colonies (2.5/nest), and (iii) an intermediate category between these two extremes (at 1.8/nest). By applying different mortality rates for different age classes of birds through the season until January, it is possible to estimate the size of the mid-winter population. Mortality rates applied were 0.4 for first calendar year birds, 0.3 for immature non-breeders and 0.2 for breeding adults in these calculations, adjusted for the elapsed time between the end of the breeding season and January. January is commonly used as the month in which numbers of waterbirds are counted.

> In 2006, the most recent Pan-European breeding census of Cormorants was organised and undertaken by WI-CRG (see Figure 6.2). In regions A and B, a total of 232,311 breeding pairs of the *sinensis* race was assessed and 52,143 breeding pairs of the *carbo* race, giving a total of almost 284,500 breeding pairs breeding in the EU-27 region, Norway and Switzerland (see Table 6.1).

Table 6.1 Comparison of Cormorant counts in 47 countries in the western Palaearctic, including North Africa and the Middle East, in summer 2006. Counts are split into three geographic regions (source: IUCN-Wetland International Cormorant Research Group).

Regional group	Summer 2006	
	Number of nests	%
(A) Atlantic-North Sea	121,763	33
(B) Baltic-Central Europe	162,691	44
(C) Black Sea-East Mediterranean	87,882	24
Total	**372,336**	

The number of immature Cormorants of one, two and three years old that have yet to start breeding (the so-called 'floaters') was estimated to be between 100,000 and 200,000 individuals for populations in regions (A) and (B) combined.

Thus, from the breeding counts in regions (A) and (B) in summer 2006, a January 2007 total of 755,300 Cormorants (*sinensis*) was estimated. This number includes the breeding birds plus both young of the year and the non-breeders. Mortality factors applied imply that the population in May (prior to hatching) would be lower and in August (maximum number of young fledged) higher than this.

How many Cormorants are there in total?

Cormorants (*P. carbo sinensis*) are distributed continuously through Europe and Asia.Thus to answer the question above in a meaningful way, the geographic area under consideration must be carefully defined. The division suggested here into three regions is a first attempt to do this. The analysis of migratory movements of ringed Cormorants could be used to further elaborate and distinguish in a more sophisticated way between different sub-populations. Nevertheless, from the overall

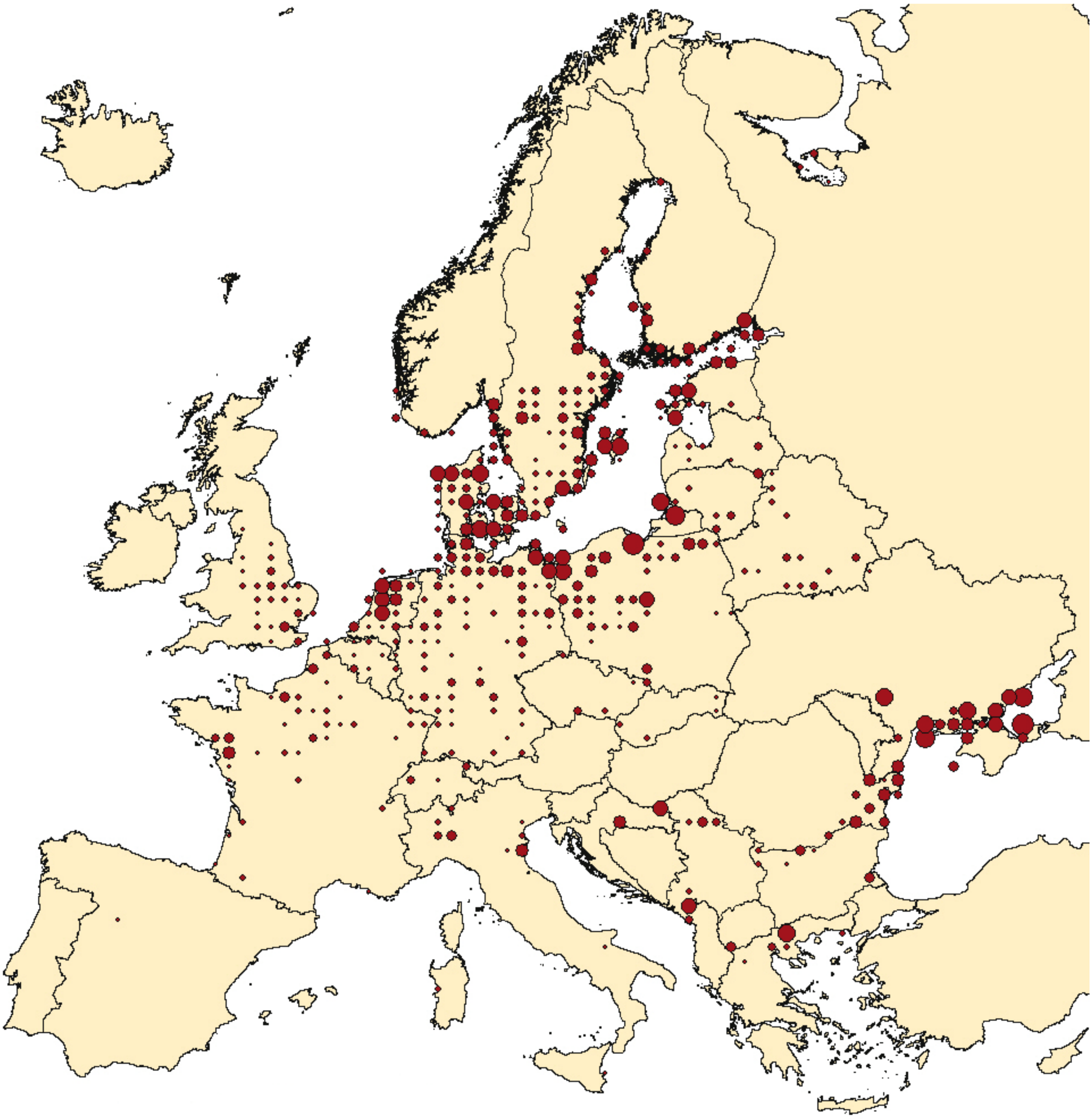


Figure 6.2 Distribution of breeding Cormorants (*sinensis*) in Europe. Notice the presence of the larger concentrations along the coastal (lowland) regions. Data are presented per 50 x 50 km grid cell, showing clearly the concentrations in the Baltic-North Sea as well as in the NW Black Sea region. Data for Turkey have not been included in this map, due to incomplete information at this grid cell level.

number of breeding pairs in regions (A), (B) and (C) (including both *carbo* and *sinensis* races), it is estimated that a total of 372,300 pairs of Cormorants breed.

However, the number of breeding pairs is not just doubled to arrive at an estimate of total numbers. The young birds of the year and the non breeding part of the population also have to be taken into account. In the westernmost part of the range we have data to compare summer and winter numbers; ringed birds provide estimates for mortality and counts in colonies produce data on breeding success, which is the number of fledged young per couple that have started breeding. Applying this conversion factor as derived for *sinensis* birds in regions (A) and (B) (i.e. a conversion estimate of 3.25 from the numbers of breeding pairs to the number of individuals in the following January), produces a tentative estimate for January 2007 of 1.2 million birds in the entire pan-European range (i.e the Western Palearctic extending well beyond EU- boundaries). Of these, 755,300 Cormorants were estimated to be present in regions (A) and (B) combined. The latter number corresponds essentially to the EU-27 countries plus Switzerland and Norway estimated for January 2007.

6.3 Winter distribution

Cormorants spend their winter in a wider geographical range than they do during summer: generally more to the south, mainly because of the freezing-over of the freshwater habitats they are using most of the

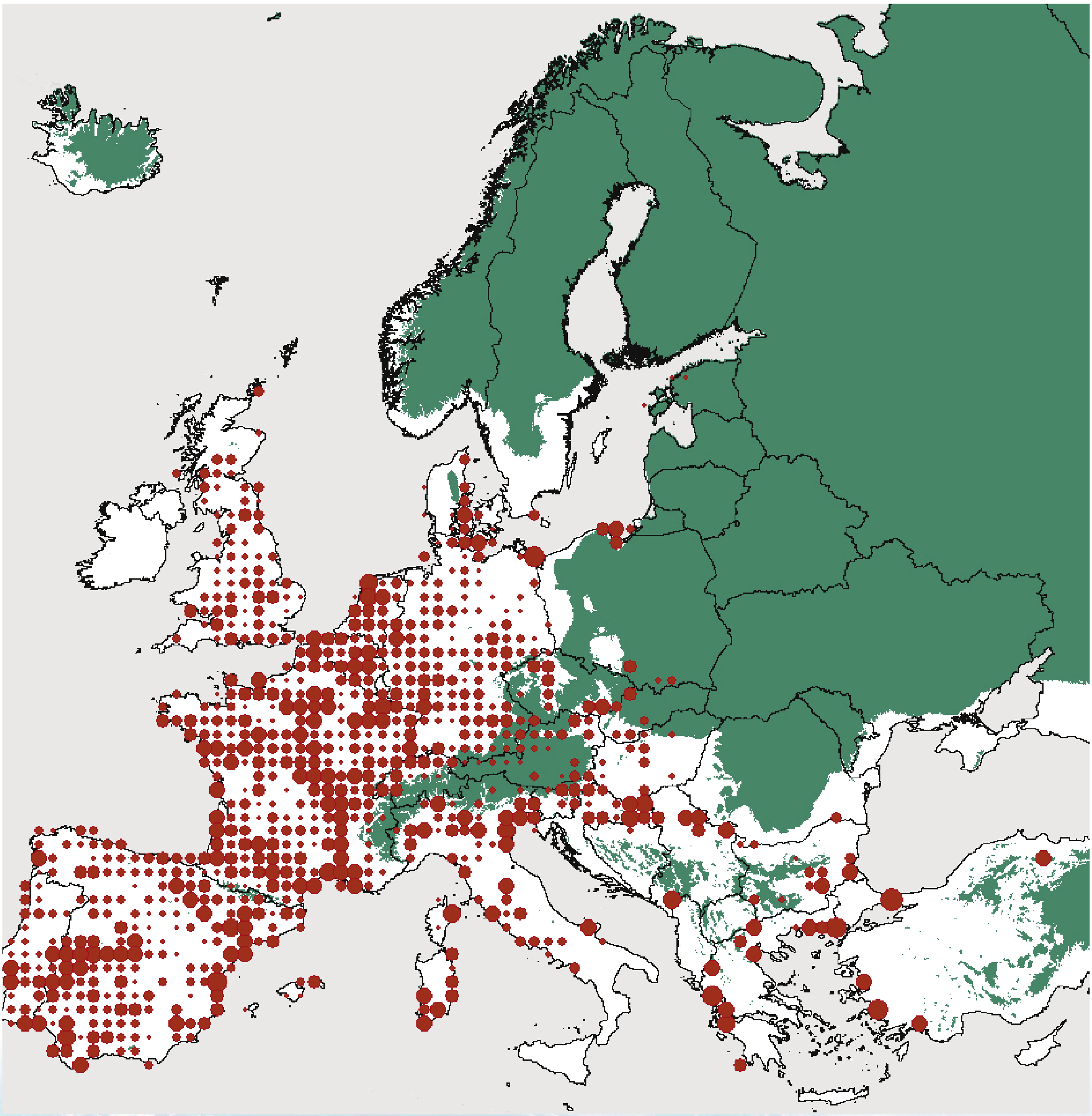


Figure 6.3 Distribution of Cormorants in Europe in January 2003. Only geo-referenced data are shown, thus excluding most *carbo* birds in Norway, Iceland and Ireland, as well as birds in Ukraine, Russia and parts of Turkey. The green area depicts regions experiencing an average winter temperature below -5.5°C which largely coincides with areas not used by wintering Cormorants.

Using data from about 2,500 roosts, complemented by counts of Cormorants at water bodies made during the International Water bird Census (IWC) in January coordinated by Wetlands International, an overall total number of almost 676,000 Cormorants was assessed in all three geographic regions together (Table 6.2). Half of this total was in the Atlantic-North Sea/ Western Mediterranean area and one third in the Baltic-Central European area. Regions (A) and (B), including the greater part of west and central Europe, thus held a combined total of 561,000 Cormorants.

Table 6.2 Comparison of Cormorant counts in 47 countries in the Western Palaearctic, including North Africa and the Middle East, in January 2003. Counts are split into three geographic regions, similar to the breeding count. Notice the shift in percentage use of zone A compared to B between summer and winter (Table 6.1), indicating the increased importance of zone A in winter.

Regional group	January 2003	
	Number of birds	%
(A) Atlantic-North Sea	346,524	51
(B) Baltic-Central Europe	214,413	32
(C) Black Sea-East Mediterranean	114,898	17
Total	675,835	

time. The pan-European attempt to count Cormorants in winter was first organised in 2003. The main aim was to assess the mid-winter distribution of the birds in Europe and beyond and to compare winter numbers with counts during breeding time. Counting Cormorants in winter is more time consuming than a breeding census as birds are scattered over vast territories.

The January 2003 count (see Figure 6.3) gave an estimated total number of 427,000 *sinensis* birds and 134,100 *carbo* birds, mostly confined to coastal (lowland) areas. As can be seen from Table 6.2 the majority of Cormorants (51%) winter in Western Europe, with much lower numbers wintering in central (32%) and eastern (17%) Europe. This is largely due to the fact that many waters in central and Eastern Europe freeze and thus become unavailable as feeding sites in winter. Please see chapter 12 for discussion and further interpretation of these assessments of Cormorant numbers.

7 CORMORANTS BREEDING IN EUROPE: EXPLANATORY FACTORS

7.1 Climatic aspects

The rationale behind this analysis is that as climatic factors differ considerably across Europe, this may have a large impact on the breeding and wintering conditions experienced by Cormorants. By analysing European climatic conditions, it might be possible to interpret some of the key driving forces behind the distributional patterns of Cormorants at the continental level. Temperature was considered to be the main factor affecting the birds' distribution. In winter freezing temperatures limit the availability of fishing waters whilst temperature sets

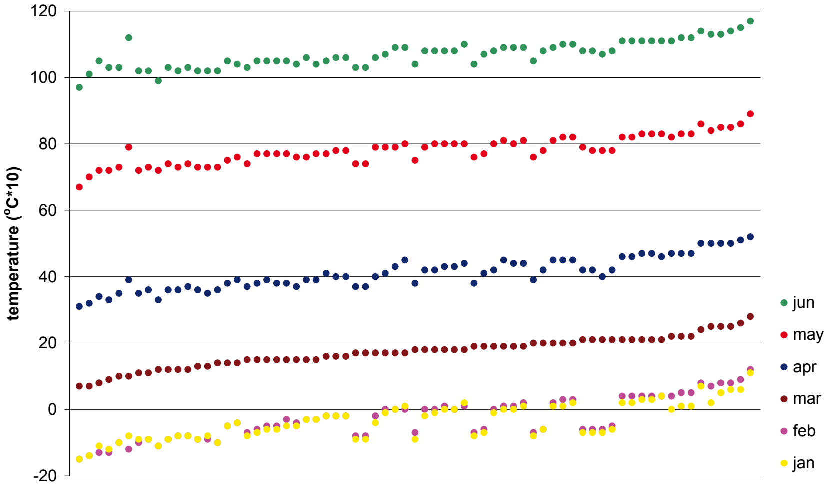


Figure 7.1 Average minimum air temperature at Cormorant breeding colonies in the Netherlands in different months. March is important here as it is the month with the earliest recorded start of Cormorant breeding in the Netherlands. During this month such early breeding occurred when median air temperature = 1.8°C, (average = 1.7°C, range = 0.7–2.8°C). X-axis shows the ranking of all data points in March, from lowest (left) to highest (right), the other months are derived from this.

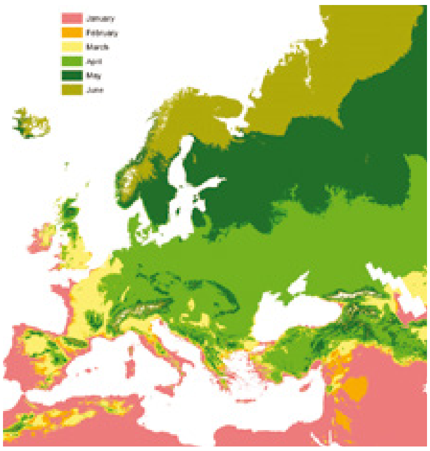


Figure 7.2 Months in which average minimum temperature 1.5°C is reached across the European continent, ranging from January to June. This illustrates the calculated possible start of Cormorant breeding across Europe, based on temperature development.

Cormorants breeding in Europe have more than four months difference in the temperature-dependent timing of the start of their egg-laying. Displaying male bird. Photo courtesy of Florian Möllers.

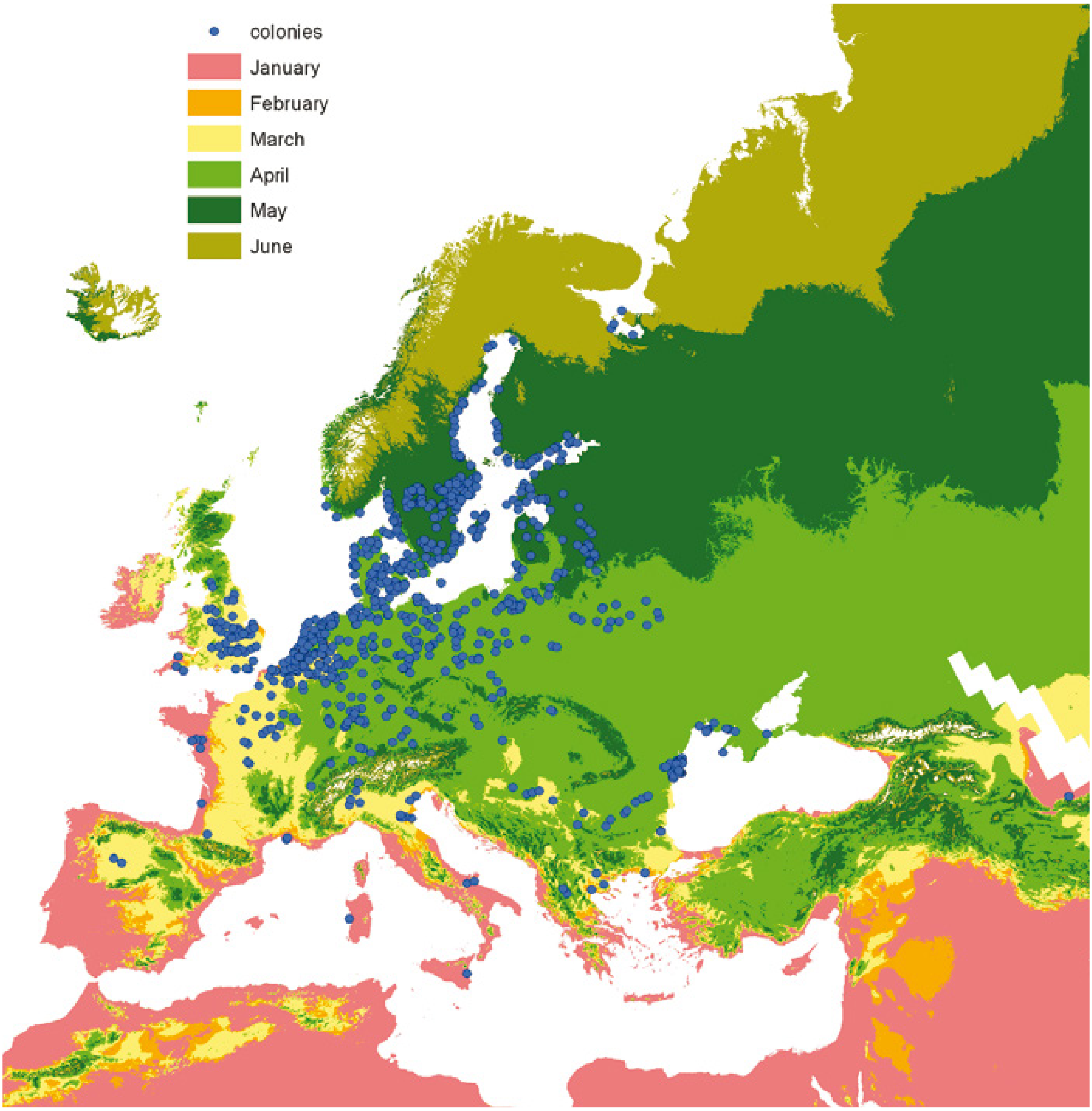


Figure 7.3 Months in which an average minimum temperature of 1.5°C is reached in relation to (*sinensis*) main Cormorant breeding colonies (indicated by blue dots).

the biological timing of events in spring. The spawning of fish, their swimming speeds, and also the energetic costs of Cormorant foraging are all related to temperature.

For analyses, climatic data at three characteristic periods were used: (1) the time of onset of Cormorant breeding in spring, (2) the period when young birds fledge, and (3) during mid-winter. Spring temperatures (average minimum) in relation to the onset of Cormorant breeding at various places in Europe were explored. For calibration, data were used from The Netherlands, Belgium, Italy and Finland. Climatic data at the time of fledged young was assessed across pan-European and North African regions by looking at temperature changes at these sites 90 days after the start of breeding, so as to reflect conditions at the time of fledging. The mid-winter distribution of Cormorants was considered in relation to the average temperature in January, importantly this corresponds to the period when Cormorants are counted at mid-winter roosts.

Data from detailed observations from the Netherlands show that, on average, the majority of Cormorants start to breed in March. A closer look at the minimum temperature in March for all colony sites in The Netherlands shows an east-west gradient within this rather small territory of almost 2°C. This temperature gradient (effect of the North Sea) can also be observed from data on the commencement of breeding, with birds in the southwest breeding earlier than those in the northeast of the country. By taking the minimum March temperature at 50% of the colonies (quartiles 2–3) as the average start of breeding we found a temperature of 1.5–2.1°C (Figure 7.1).

In subsequent analysis, 1.5°C (Q1) was adopted as an estimator of the average temperature at the start of the Cormorant breeding period. The place where and when this temperature is reached was thus assessed in relation to Cormorant colonies throughout Europe.

There is a gradient across Europe with regard to the period at which minimum temperature for breeding (1.5°C) is reached (Figure 7.2). This gradient runs from southwest-northeast Europe and occurs sometime from January to May depending on location. This 'temperature threshold' nicely corresponds to the months when Cormorants actually breed in these regions (for distribution see Figure 7.3). There are records of an early start to breeding in January in south and north-east Italy and of a late start to breeding in northern parts of the Baltic Sea at the end of May. On the map there is obviously a vast area around the Baltic that would be suitable for Cormorant breeding from this perspective. On the Atlantic side, the month of March covers a significant area whereas in Eastern Europe this is not the case. As a whole, the shift in spring temperature is more advanced but also slower in the west than in the east, probably related to the effect of the Gulf Stream. Breeding occurs in a SW to NE sweep according to the average minimum temperature threshold of 1.5 degrees. So, it starts as early as January/February in SW Europe, in March in UK, F, NL, in April for large parts of central/eastern Europe and in May for Northern parts of Baltic and finally June for northern Norway and Finland.

Temperature at breeding sites at time of fledged young

Besides minimum temperature in relation to start of breeding, it was also tested whether temperature during the fledging period would be important. For this, temperature at known breeding sites three months after presumed start of breeding (i.e. at or above an average temperature of 1.5°C) was analysed. Because this fledging period corresponds to summertime, it was not expected that minimum temperatures would be important — rather it would be the maximum temperatures which could have an effect on thermoregulation of the nestlings and/or conditions in the shallow feeding waters.

Analysis showed that at no breeding site in Europe did maximum temperature during the fledging period reach, on average, more than 30°C. Figure 7.4 shows the distribution of all colonies with respect to this temperature at the time that the young birds are fledging.

As can be seen from Figure 7.4, the average temperature at Cormorant colonies three months after the onset of breeding is 20.9°C. The distribution appears to have two peaks, one at 20–21°C and one around 24°C.

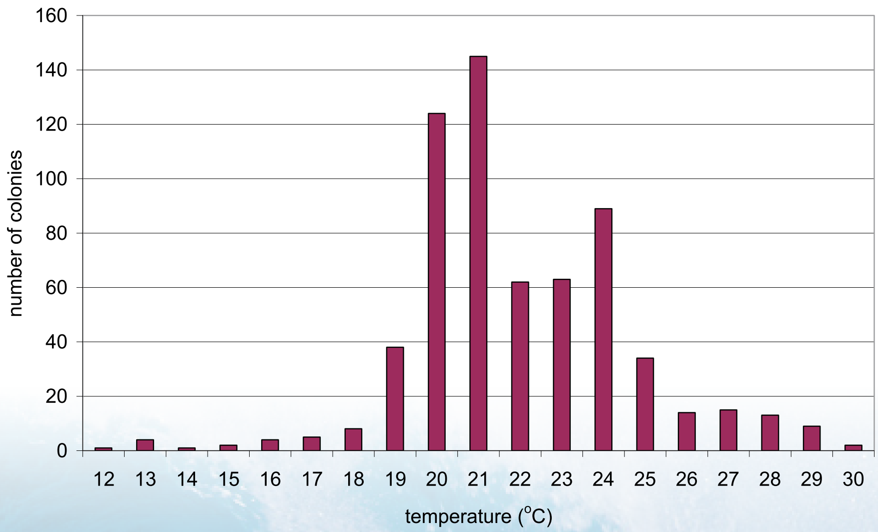


Figure 7.4 The number of Cormorant colonies in relation to the local maximum temperature during the fledging period of young (Q1=19.9°C, Q3=23.3°C, Median=20.9°C, min-max: 12–30°C).

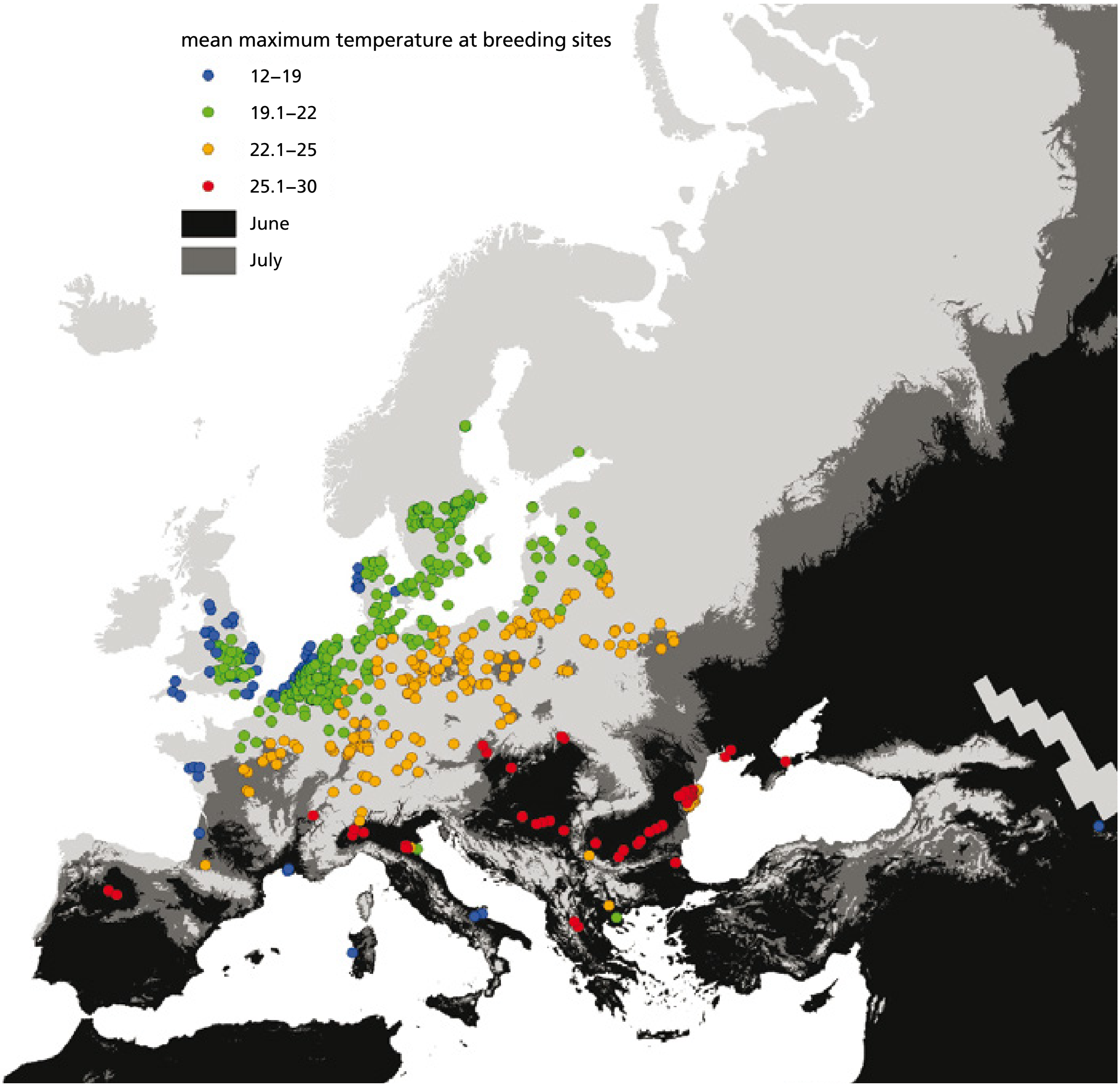


Figure 7.5 Mean maximum temperatures at Cormorant breeding colonies (dots) and areas where an average maximum temperature of 24°C is exceeded in June and/or July (black and darkest grey areas), that is at the time of fledging of young birds. Birds from colonies in the warmest temperature range (red dots) are known to move out of these areas towards cooler areas during the summer. This is partly also true for areas where the maximum temperature at time of fledging is greater than 22°C (yellow dots).

Figure 7.5 shows these temperatures mapped in relation to the individual colony sites in Europe (for *sinensis* only). The coolest sites during the fledging period occur around the Atlantic and North Sea shores. The majority of all colonies are found in an area ranging from central England, The Netherlands, Denmark, and Southern Sweden all the way east to the Baltic States. Although many colonies occur in the zone just south of this (i.e. central France, Germany, Poland and Belarus), average colony size here is smaller than elsewhere. Few colonies occur in the area where temperatures during the fledging period reach more than 25°C, these are restricted to the interior parts of Spain, Italy, along the Danube and the northern edge of the Black Sea. Temperatures around 25°C are probably ecologically the highest the birds can cope with, and this is corroborated with data on post-fledge movements. At many colonies young disperse well out of the area of actual breeding and almost all birds move out of the area where the maximum temperature during the fledging period is greater than 24°C. Many even move out of the area when temperatures exceed 22°C during this period in the breeding cycle. The post-fledge staging sites around the North Sea and Baltic Sea are situated in an area occurring just below of this temperature range. According to the analysis, such areas do not exist in the greater part of the coastal Black Sea and Azov Sea, as well as for the greater part of the coasts of the Mediterranean which seem simply too hot at this time of year. Interestingly, some exceptions occur in the river Rhone and Po Delta, Sardinia and Puglia in Italy as well as coastal parts of Macedonia in Greece.

The important conclusion from these analyses is that the distribution patterns and movements of Cormorants (in terms of where and when birds breed and where birds may move from after breeding/fledging) correspond with known temperature gradients across Europe. These relationships could thus be used to explore future developments (e.g. colonisation patterns and/or effects of global change).

8 CORMORANTS WINTERING IN EUROPE: EXPLANATORY FACTORS

The rationale behind this analysis is that habitat availability is a vital factor in determining the ecological tolerance of an area for Cormorants in winter. Describing the available space in relation to a temperature gradient and habitat availability will provide a better view of the ecologically based dispersion patterns of Cormorants across Europe.

8.1 Choice of the study area

The winter distribution of the Great Cormorant used in this analysis was constructed using the Wetlands International Cormorant Research Group (WI-CRG) coordinated night roost count of mid-January 2003. Analysis was concentrated on a large geographic area, with homogeneous data quality, encompassing most of the *sinensis* wintering population from regional groups A and B (see Figure 6.1 map). This area covers South-West Europe (excluding Portugal), north to southern Scotland and Denmark, east to Poland and Hungary, and south to central Italy (see Figure 8.1). This study area is approximately 3.1 million km² and includes 1,242 50 x 50 km grid cells where environmental variables have been calculated (note: each grid cell thus represents 2,500 km² or 250,000 ha). The number of birds observed in this area during the January 2003 count was approximately 370,000, which accounted for 65% of the estimated European population of Cormorants at that time, including the *carbo* race.

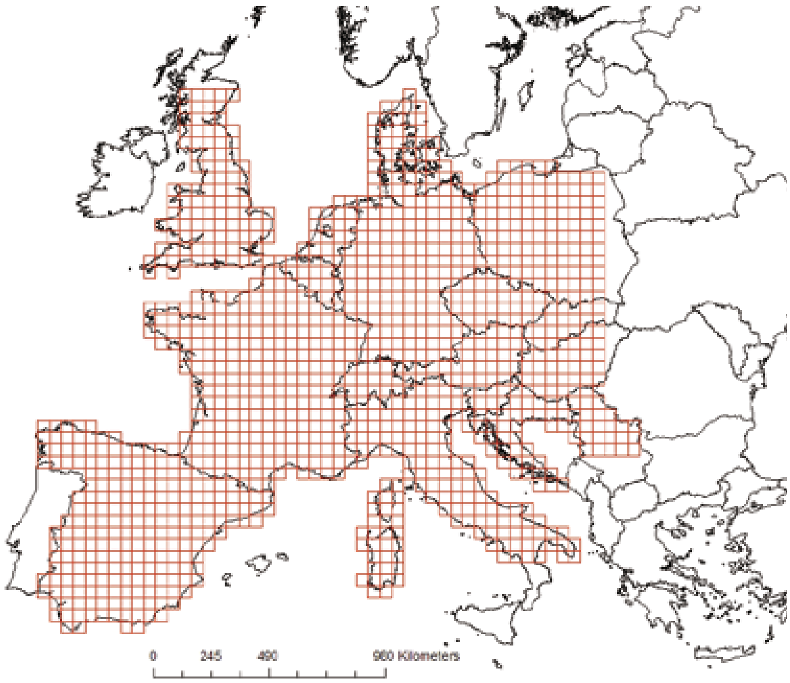


Figure 8.1 Map of Europe showing the sub-set of 1,242 grid cells (50 x 50 km) used for analysis in the present study.

8.2 Exploring the water surface area/climatic patterns in the study area

In order to describe how the environmental conditions vary across the study area, several maps were drawn (Figures 8.2 to 8.5) and a multivariate analysis (Principal Component Analysis) was performed in order to understand relationships and patterns between the variables.

Temperature

Figure 8.2 shows the average minimum temperature in January in the study area. A strong southwest to northeast gradient in ambient (air) temperature is visible, clearly showing the effect of the continental land mass as well as the influence of the relatively warm Gulf Stream, generally showing cooler temperatures inland and towards the east. Notice the high mean temperatures along the coasts of Sardinia.

Depth profiles along the coast

The coastal waters immediately adjacent to the mainland differ with respect to average depth. Figure 8.3

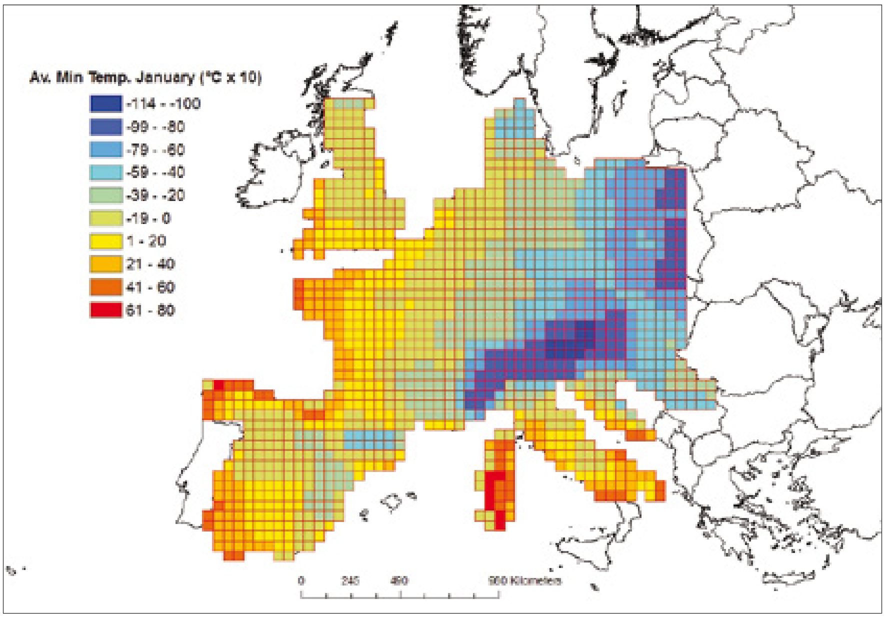


Figure 8.2 Average minimum temperatures in January for each 50 x 50 km grid cell covering the study area.

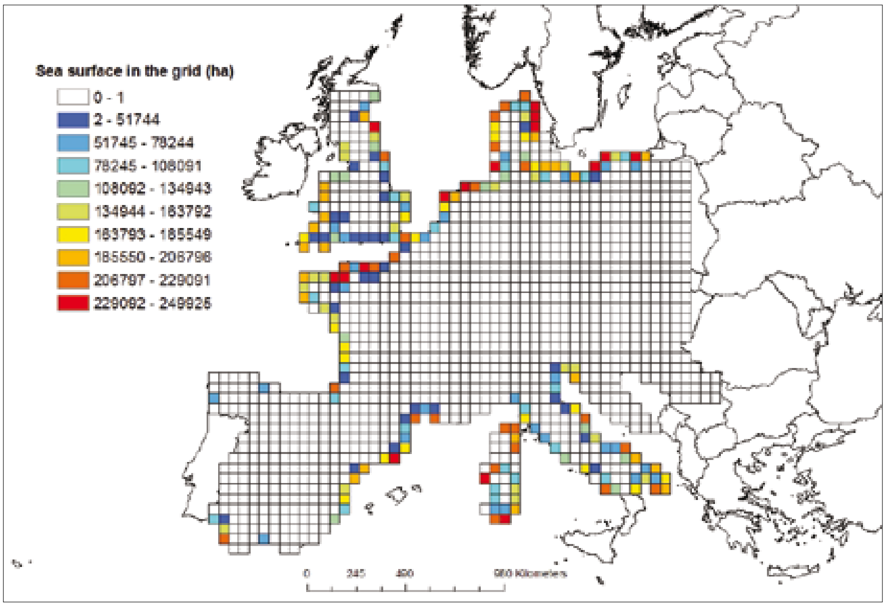


Figure 8.3 The sea surface area of shallow waters for each 50 x 50 km grid cell containing shallow water (i.e. surface area for water of less than 25 m deep).

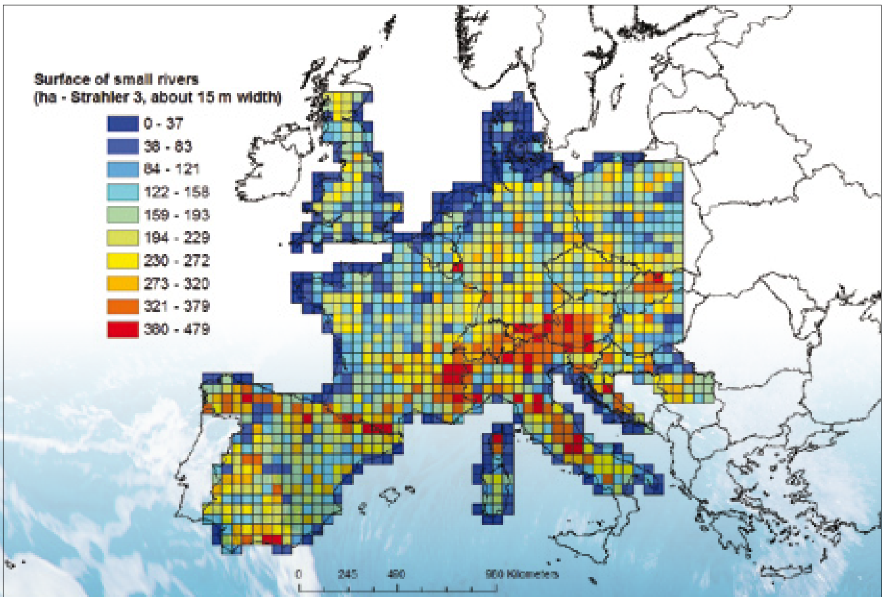


Figure 8.4 The surface area (ha) of small rivers (Strahler category 3, estimated width = 15 m) within 50 x 50 km grid cells. The mountainous areas are clearly visible because of the high density of small streams there.

shows contrasting differences in pattern between the more shallow coastal areas around the North Sea, Baltic and Atlantic coast of France and the much deeper and steeper coasts along the mountainous parts of the Mediterranean and Adriatic. The Spanish north coast between San Sebastian and Vigo, the SE coast from Gibraltar to Cartagena, the French and Italian Riviera coasts between Marseille and La Spezia as well as the coast of the Adriatic in Western Balkans are particularly steep.

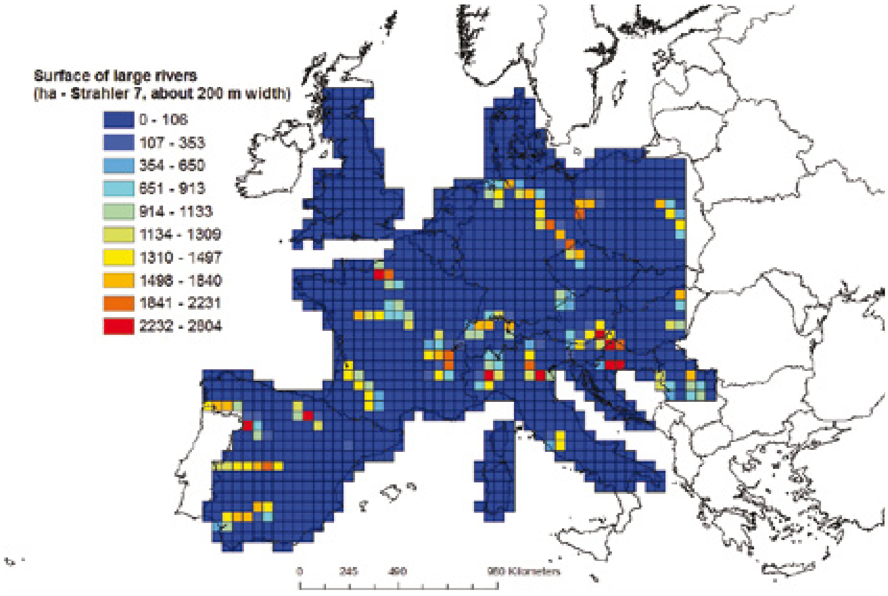


Figure 8.5 The surface area (ha) of larger rivers (Strahler category 7, estimated width = 200 m) within 50 x 50 km grid cells.

Water inland

In relation to the 'availability' of surface waters on land, Figure 8.4 shows the occurrence of small rivers (Strahler category 3). The mountainous areas in Europe show up well in this figure because of the high density of small rivers in these regions. By contrast, the presence of large rivers is far less common. For example, Figure 8.5 shows the occurrence of Strahler category 7 rivers across this part of Europe. Note the difference in the

Young Cormorants tend to winter under more temperate climate conditions than others. Colour-ringed Dutch-born Cormorant (E/R) in first winter plumage recorded wintering in France. Photo courtesy of S van der Putten.

Table 8.1 Principal Component Analysis showing the correlation between the first three axes and the environmental variables. Significant factors are shown in bold.

	PC1 axis	PC2 axis	PC3 axis
Variance explained	25.2 %	14.0 %	9.9 %
Average minimum temperature in January	0.27	**0.51**	0.15
Coastal surface area	**0.36**	-0.03	0.07
Lake surface area	-0.08	-0.21	-0.07
Strahler 2 river surface area	**-0.46**	0.14	-0.19
Strahler 3 river surface area	**-0.43**	0.12	-0.19
Strahler 4 river surface area	**-0.35**	0.13	-0.29
Strahler 5 river surface area	-0.28	0.08	0.05
Strahler 6 river surface area	-0.16	-0.11	**0.40**
Strahler 7 river surface area	-0.11	-0.04	**0.40**
Strahler 8 river surface area	-0.06	**-0.21**	**0.43**
Strahler 9 river surface area	0.00	-0.11	0.17
Latitude	0.12	**-0.49**	-0.26
Longitude	-0.10	**-0.58**	-0.07
Diversity of water types	**-0.36**	-0.01	**0.46**

absolute value of the surface areas involved in these three aquatic habitat maps. Shallow sea surface areas (see Figure 8.3) constitute the largest areas, followed by larger rivers (Figure 8.5) and then small rivers (Figure 8.4). This means that, in relation to habitat type, the total area of water suitable for Cormorants is divided in an unusual way. The water surface area in regions with the highest density of small rivers never reaches the level of water surface area associated with even a single, or a few, large river sections. Moreover, when coastal shallow water is considered, the surface area of this habitat type greatly exceeds that of any freshwaters on a 50 x 50 km grid cell basis.

A PCA was carried out with all 14 environmental variables used in the present analysis, in order to explore the general environmental variation across the study area (see Table 8.1).

The first axis (PC1) accounted for 25% of the total variability in wintering Cormorant numbers. PC1 is positively correlated with shallow coastal water surface area and negatively correlated with all small river surfaces, as well as with the variety of water types (Table 8.1 and Figure 8.6). PC1 is only poorly correlated with geographical coordinates. Thus, PC1 separates the coastal, low altitude areas used by Cormorants in winter from the higher altitude, smaller river areas. The second axis (PC2) accounted for 14% of the variability in wintering Cormorant numbers. PC2 is strongly correlated with higher average minimum January temperatures, and also with the north-eastern coordinates, thus it reflects the strong north-east to south-west gradient in European winter conditions (Figure 8.7). The third axis (PC3) accounted for 10% of the variability in wintering Cormorant numbers and was especially positively correlated

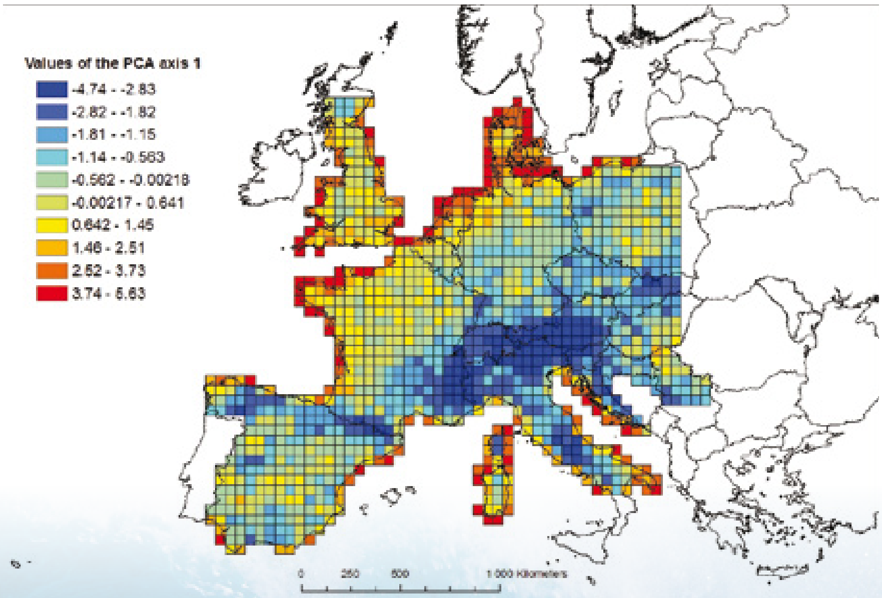


Figure 8.6 Spatial representation of the PC1 axis (explaining 25% of variation in winter Cormorant numbers), separating potential Cormorant foraging habitat (available water surface area) in coastal versus high altitude habitats.

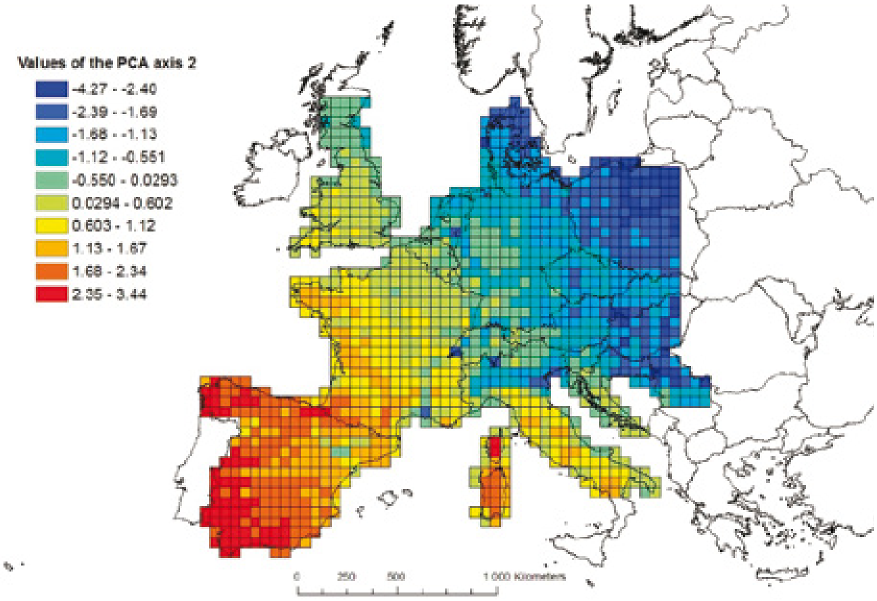


Figure 8.7 Spatial representation of the PC2 axis (explaining 14% of variation in winter Cormorant numbers), showing a northeast to southwest gradient, primarily the result of average minimum January temperatures.

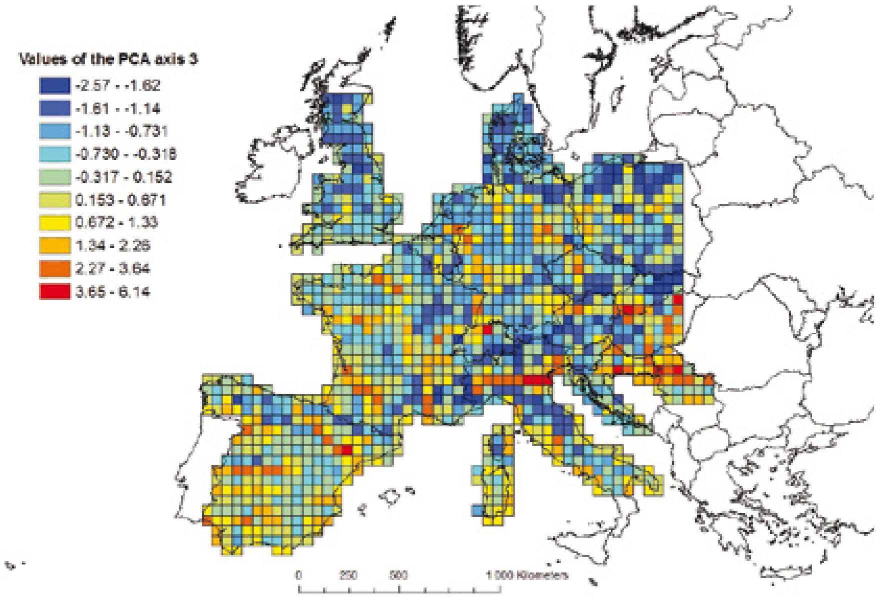


Figure 8.8 Spatial representation of the PC3 axis (explaining 10% of variation in winter Cormorant numbers), which fits well with the presence of medium and large river systems and to an increased diversity of aquatic habitat types.

with medium to large rivers, as well as with a high diversity of water types (Figure 8.8). On this map, high values of PC3 are clearly concentrated on major river systems (e.g. Ebro, Rhône, Po, Danube, Rhine) even at 50 x 50 km resolution.

This analysis suggests that it is meaningful to use the the three PCA axes as basic ‘synthetic descriptors’ of water and climate conditions within the study area in relation to the distribution of wintering Cormorants there. How is the Cormorant distribution related to these synthetic descriptors?

A plot of the 1,242 grid cells projected along the first two PCA axes is given in Figure 8.9, showing cells with or without Cormorants. There is no clear segregation of Cormorant presence/absence in this two-dimensional space, except that negative values on the PC2 axis (i.e. the northeast-southwest temperature gradient) seem to be more correlated to the absence of Cormorants. This is mainly due to the absence of wintering birds in the northeast corner of the study area (e.g. in Poland) during the 2003 census. It is noteworthy that PC1 (coastal versus high altitude) does not seem to be of importance in explaining the presence/absence of Cormorants in winter. This may be a reflection of the very wide environmental adaptability of the species in its winter range, but also of the differing availability of fish in winter relative to the different habitat types present. More specifically the availability of fish (e.g. species, size in relation to water depth, water current velocity, underwater visibility etc.) is not equally distributed across the water bodies but varies independently.

Pearson correlation analysis of the log-transformed value of the number of wintering Cormorants (excluding the cells where no Cormorants were observed), shows that Cormorant numbers are neither correlated with PC1 (coastal versus high altitude, $R = 0.045$, $p = 0.231$), nor with PC2 (northeast-south west temperature gradient, $R = -0.022$, $p = 0.552$). These two major environmental descriptors thus do not explain the overall patterns of

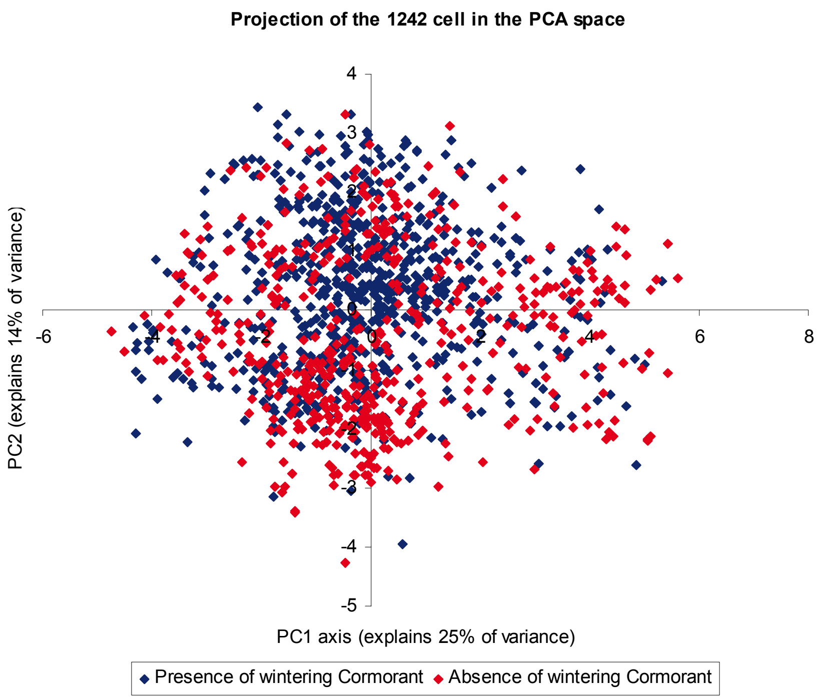


Figure 8.9 Projection of the 1,242 grid cells in the space defined by the first and second axes of the PCA in relation to the presence/absence of wintering Cormorants.

Cormorant abundance in winter. Again, this suggests that, within the limit of the birds' winter range (probably primarily determined by the climate), Cormorants in winter are not simply confined by the overall surface area of the various water types available in Europe.

However, the abundance of Cormorants in winter is positively correlated to the 'major river system' variable (i.e. PC3, R = 0.347, p <0.001). Within the wintering range, areas with the highest Cormorant abundance fit with the major river systems, regardless of the geographical context of these systems (i.e. southern or northern, continental or maritime parts of the range). This GIS-based analysis of Cormorant wintering distribution across much of Europe is summarised and interpreted in Text Box 8.1.

Cormorants in winter seem to have a European wintering range determined by temperature limits. Within this 'temperature window', the birds are widely distributed, showing a strong tendency to be more abundant in the regions of the major river systems (i.e. large river valleys and associated floodplains). Based on the presence of suitable foraging habitat, there is no clear evidence that, within the geographical wintering range, regions are used to capacity by Cormorants. Except for large river systems, probably other factors (such as fish availability) are highly variable and therefore may determine Cormorant distribution in greater detail (see chapter 9). However, if the temperature window is modified (e.g. by climate change), it is highly probable that more aquatic habitat will become available to Cormorants due to the fact that more potential habitat is available in the north-east of the region than it is in the south-west and southern parts of Europe.

Text Box 8.1 Summary of GIS-based analysis of European Cormorant wintering distribution.

9 THE WATER SYSTEMS DATABASE

The rationale behind this data collation and exploration is that analysis of more detailed data on the relationships between Cormorants and their use of feeding habitats, diet and their foraging densities at specific water bodies would provide important information about the role of these avian predators in these water systems.

9.1 Introduction

Water surface area is considered an important variable that accounts for the total number of Cormorants or, more precisely, the total number of bird days (i.e. an index of 'habitat use' calculated as the number of birds x the number of days the birds are present at a specific location). The critically significant factor affecting the density of birds, however, is the supply of edible (i.e. relatively small) fish and its 'availability'. Prey availability is a complicated concept, covering more than the abundance of potential prey and encapsulating its 'ease' of capture. Thus, besides the abundance or biomass of edible fish, water depth and turbidity will determine the carrying capacity of a water systems (i.e. the number of Cormorants that it can support).

Nutrients and algae are an important food source for micro-organisms and macro invertebrates that, in turn, form the food supplies for fish and result in subsequent fish biomass. The nutrient balance of a water body largely depends on the surrounding land use and the input of phosphorus and nitrogen. Furthermore, human management of water bodies has changed fish communities extensively (see chapter 4). By closing off inland seas, lagoons and estuaries, by constructing artificial lakes and diverting rivers, many aquatic systems have become less natural. Fish communities have been altered and habitats become disconnected. Through their relationship with fish as food, Cormorants are likely to react to all these changes in some way.

A Water Systems Database, based on discrete water bodies, was established in order to broadly assess the relationship(s) between Cormorants and fish, and the factors that determine them. Pooled knowledge from 65 experts in 26 countries (in total, 179 different cases, see Table 9.1) of geo-referenced water bodies were included in the analysis. These waters accounted for approximately 30,000 km^2 of sampled water surface and related to a maximum number of about 350,000 Cormorants. For almost all cases, data on fish species were provided as a ranking of (i) the three most abundant species in the system and (ii) the three most common species eaten by Cormorants there. A total of 90 fish species were ultimately included in the Water Systems Database.

Ultimately, the cases included in the Water Systems database represented a large area of the European continent but tended to be concentrated a little more in eastern countries ranging from the Baltic Sea and Sweden to the Alpine zone, Italy and Greece. In Western Europe (i.e. Netherlands, Belgium, UK) cases are also well represented but in southern Europe

Table 9.1 The number of cases included in the Water Systems Database, in relation to different water body types.

Water Systems Type	Number of Cases (%)
Open sea/Shore	7 (4)
Estuaries/River delta	17 (9)
Inland sea/Large Lagoon	14 (8)
Large Lakes	44 (25)
Large Rivers	28 (16)
Streams/Small Rivers	30 (17)
Reservoirs/Small Lakes/Sandpits	21 (12)
Fish Ponds	18 (10)
Total	**179 (100%)**

considerable gaps occured, for instance in the interior parts of France and Spain (Figure 9.1). Spain did not actively participate in the **INTERCAFE** network but contributed some cases during the earlier REDCAFE Concerted Action. Outside Europe, water systems information was also obtained from Israel and Georgia.

The variety of European water systems types (see section 4.1) is strongly reflected by the geographical range of waters within the continent. Open seas, inland seas and estuaries are situated along the coasts of the western parts of Europe and outside Europe at the Black Sea coasts. Large lakes are situated in the Baltic and partly in The Netherlands, the alpine countries and Italy. Large rivers are mostly situated in the extensive lowlands of western and Central Europe and are generally absent in the north. Smaller rivers and streams are represented in a wide geographic gradient from high altitudes to lowland situations, and reservoirs are distributed similarly. Fishponds are distributed in a wide area of inland Europe but are concentrated in a belt of eastern European countries from the Baltic States and Poland to the Czech Republic and France, but also extending further southeast into the Balkan countries.

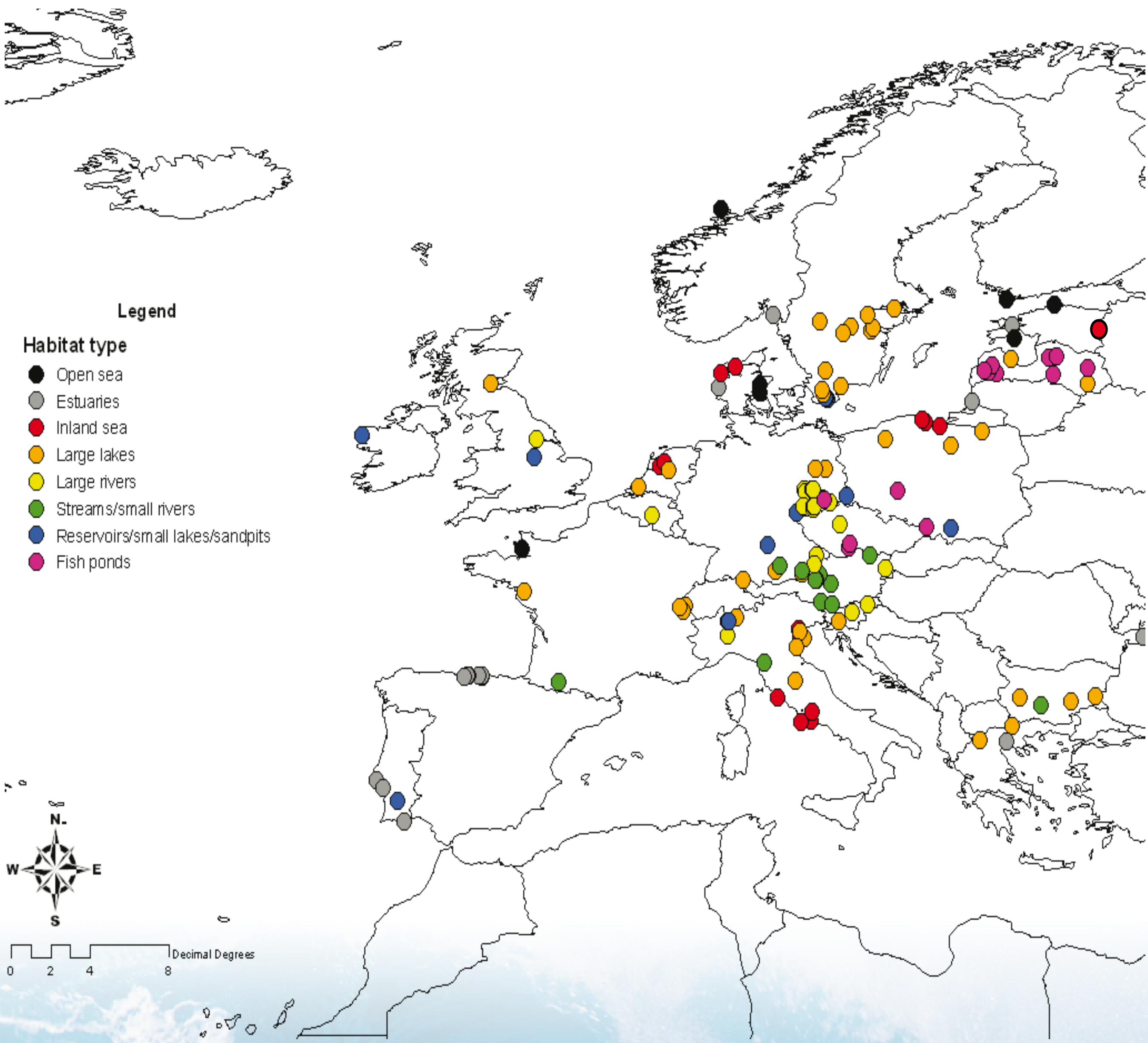


Figure 9.1 Map showing reported cases used in the Water Systems Database for Europe. Each case has quantitative data on water quality, aquatic biota and Cormorants. Cases from Israel and Georgia are not shown on the map. Eight different types of water system are differentiated.

The cases included and used in the Water Systems Database represent and describe the major European water bodies. Coastal areas are not so well represented but range from Estonia and Finland to Portugal. Other water systems types in the Database cover a representative portion of their European occurrence. Reservoirs are probably an under-represented habitat type that might account for a larger proportion of European fish-eating birds than is currently known, whilst fishpond cases are mainly from Baltic and central European countries and not from southern regions (i.e. France and Spain or the Balkans, see Figure 9.1).

Over the whole dataset, there is a clear relationship between the annual number of 'bird days' spent by Cormorants at a particular site and the surface area of the water body concerned (Figure 9.2). In absolute terms, large water bodies have far more Cormorants (i.e. more bird days, and so a heavier overall 'use' by Cormorants) than do smaller ones. However, corrected for surface area, this equates roughly to some 5,000–10,000 Cormorant days per square kilometre of water per year for smaller waters and lower at 1,000–5,000 Cormorant days per square kilometre of water per year for large surface areas.

As can be seen from Figure 9.2, the variation in the dataset is large with some individual cases diverging by a factor of around 10 (plus or minus) from this general pattern. However, the relationship clearly shows that large numbers of Cormorants and/or the length of their residence time at specific sites across Europe are associated with large water bodies. The data also indicate that smaller water bodies are more intensively used than larger water bodies as the slope of the regression line is less steep than the 1:1 relationship with water surface area.

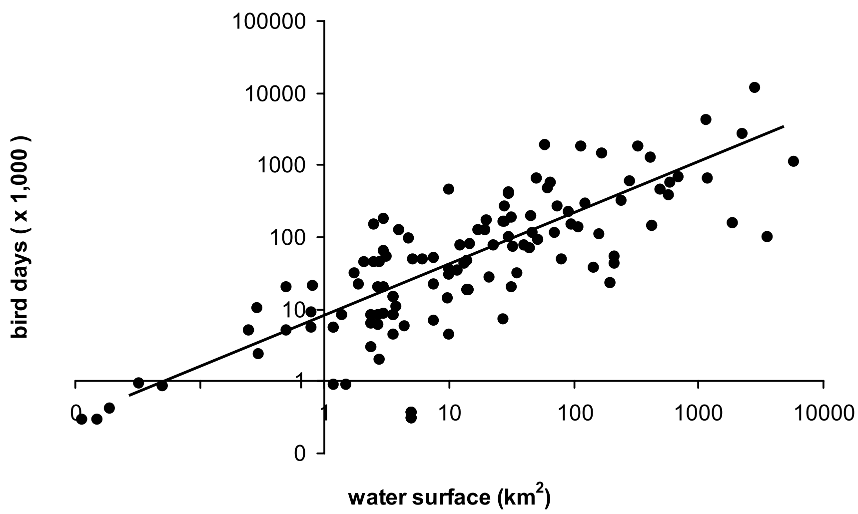


Figure 9.2 Relationship between total bird days per year for Cormorants and water surface area (N = 132 reported cases).

9.2 Water surface area and Cormorant density

The water bodies collated in the Database can be divided into either large-scale or smaller-scaled systems in terms of their water surface area (see section 4.1). Large-scaled waters are open seas, inland seas and lagoons, estuaries and large lakes, smaller-scaled ones are the large rivers, streams and small rivers, reservoirs and fishponds (Figure 9.3). A bootstrap analysis of the data for each water body type produced the mean values and 95% confidence limits shown. The water body types

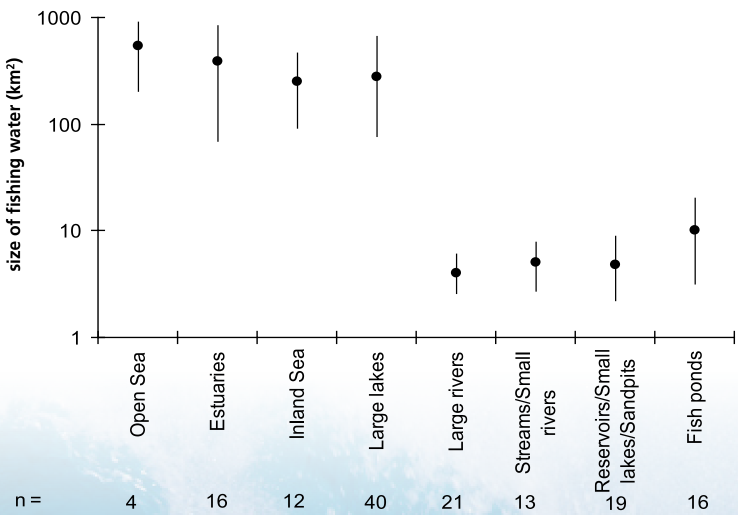


Figure 9.3 Mean size (± 95% Confidence Limits) of foraging water for different water body types, n = sample size; notice log scale (values based on bootstrap calculation).

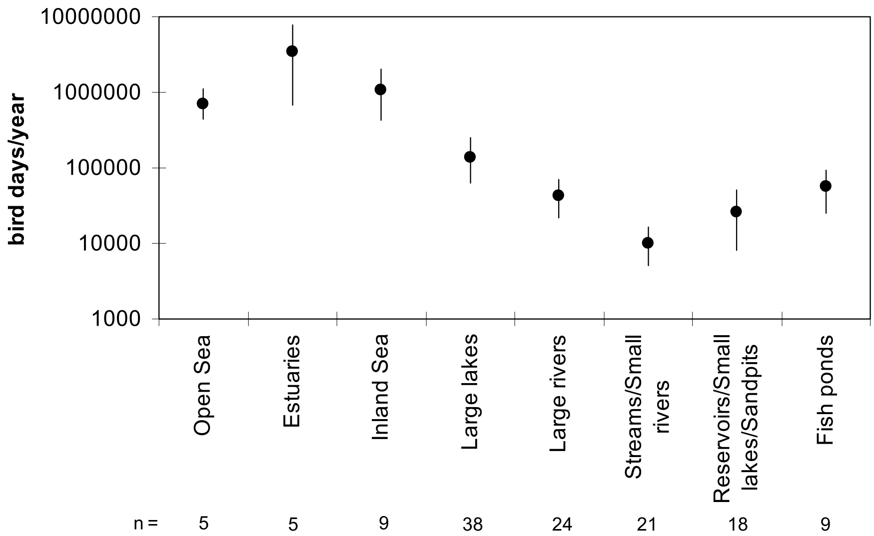


Figure 9.4 Mean number (+/-95% Confidence Limits) of bird days per year for Cormorants at different water body types, n = sample size; notice log scale (values based on bootstrap calculation).

clearly fall into the two groups mentioned above, according to the water surface area available to foraging Cormorants, the mean surface area (km^2) being approximately 50 times greater for open sea, estuary, inland sea and large lake than for the other four water body types.

Cormorant numbers are often best expressed as 'bird days', the number of Cormorants multiplied by the number of days that they are present at a specific site. The total number of bird days per year shows which habitats are most heavily used by Cormorants. Although the number of cases for the different water body types is not equally distributed over Europe and the sample size of open sea and estuary cases is too small to get reliable results by bootstrap analysis, there are clear differences in the number of bird days between water body types. The large systems (i.e. open seas, inland seas and estuaries) carry the largest number of bird days (Figure 9.4, note logarithmic scale). The mean values for these three habitat types showed no significant differences (i.e. overlapping confidence limits) and were much higher than those of other water body types. Large lakes, large rivers, reservoirs and fishponds also did not differ significantly from each other but they did have significantly lower numbers of bird days than did the large-scale systems. The smallest mean value for bird days was calculated for streams and small rivers, and this was significantly lower than all other water body types except reservoirs (Figure 9.4).

Cormorant presence, as measured by the average number of bird days spent at a site, is thus largely related to the size of the water body used for foraging (compare Figures 9.3 and 9.4). Streams and small rivers have the smallest average number of bird days, and reservoirs, small lakes and fishponds are similar to each other, having more bird days. By contrast, the largest number of Cormorant days throughout the year are recorded on estuaries, followed by inland seas, shallow coasts and large rivers being only slightly less heavily used. The important conclusion from this analysis is that the large-scale water bodies in Europe are used most by Cormorants.

A different picture of Cormorant use of water systems is apparent if bird days are examined in relation to water surface area in terms of bird density ('Cormorant days per hectare per year', see Figure 9.5).

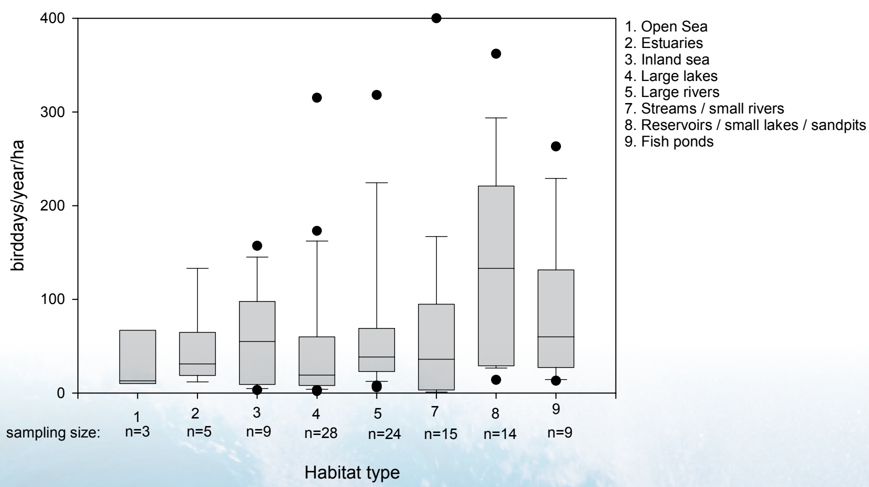


Figure 9.5 Relationship between Cormorant density (bird days/ha/year) and water body type. Box plots showing data range, 95% Confidence Limits and 75% percentiles of values around the median.

Although samples are small (especially for the number of site-specific datasets for open seas and estuaries), there is a trend towards higher average Cormorant densities in the smaller-sized water bodies like the reservoirs and fishponds. To some extent this is also true for the inland seas and lagoons. Almost all median annual density values are less than 100 bird days per ha, and only reservoirs/small lakes/sandpits have a higher density (Figure 9.5). These high Cormorant density water systems all share the fact that they are artificial, man-made waters. The natural waters such as open seas, estuaries, large lakes, large rivers and small rivers clearly have the lowest densities of foraging Cormorants (Figure 9.5).

The analysis thus suggests that artificial water bodies attract Cormorants in higher densities than do other water systems. However, the overall number of birds in relation to their duration of stay is always small at these foraging sites and Cormorants are most numerous in the large natural waters of Europe.

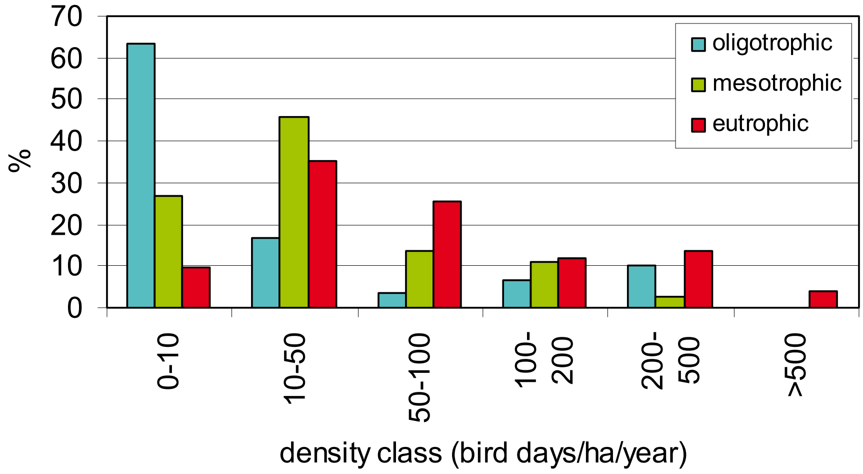


Figure 9.6 The frequency of Cormorant density classes (bird days/ha/year) for water bodies of increasing nutrient levels (oligotrophic, mesotrophic and eutrophic) in Europe.

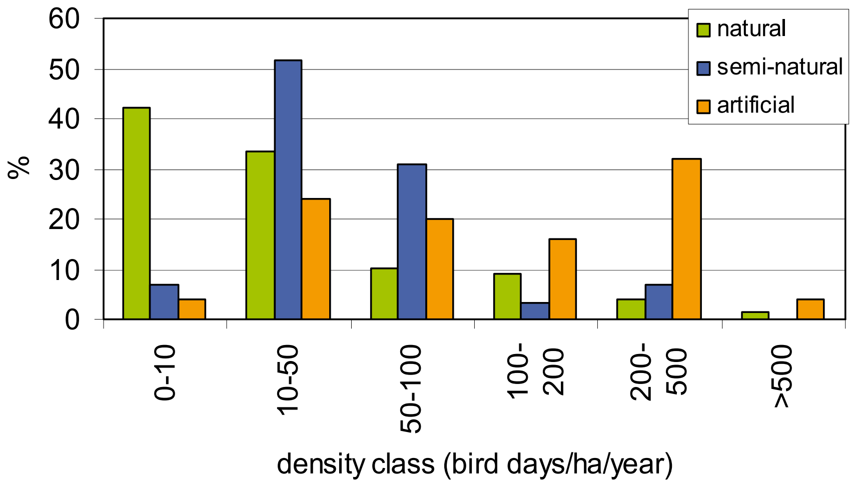


Figure 9.7 The frequency of Cormorant density classes (bird days/ha/year) for increasingly less natural water bodies (natural, semi-natural and artificial) in Europe.

9.3 Water quality

Trophic state (i.e. overall productivity based on the availability of nutrients) can also determine the distribution of Cormorants (see Figure 9.6). The lowest Cormorant densities occur in oligotrophic water systems (i.e. those with low nutrient levels), whilst intermediate densities are mostly recorded on waters of higher nutrient status (i.e. so-called mesotrophic and eutrophic waters). The highest Cormorant densities (more than 50 bird days/ha/year) are often reported from eutrophic water bodies (i.e. those with highest nutrient status). Waters of a higher trophic level thus appear to attract more Cormorants than do other water body types.

Another factor to explore is the effect of the ‘naturalness’ of water bodies on Cormorant numbers. Generally, the lowest Cormorant densities occur in natural water systems, intermediate Cormorant densities are mostly recorded on semi-natural waters, whilst the higher Cormorant densities (of more than 50 bird days/ha/year) are often associated with semi-natural and artificial water bodies (Figure 9.7). Extremely high Cormorant densities are actually strongly related to artificial water systems which clearly implies that more ‘unnatural’ waters attract greater Cormorant numbers.

9.4 Fish biomass

Relatively few quantitative data exist on fish density in absolute terms in many European freshwater

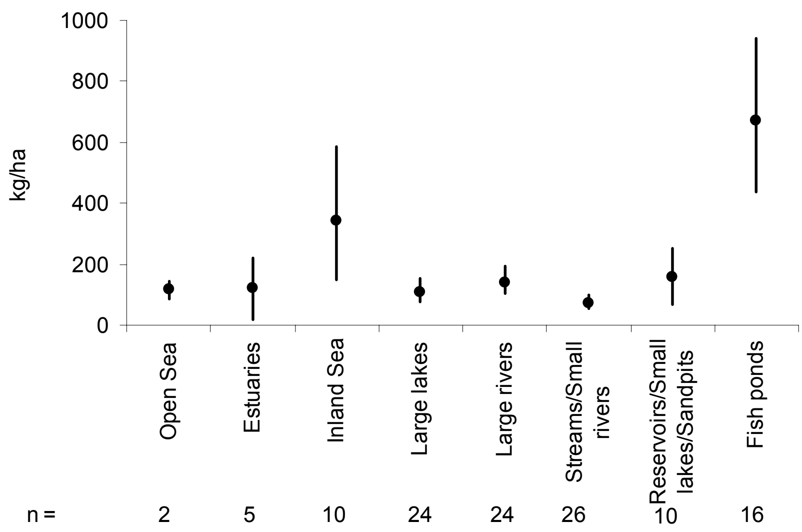


Figure 9.8 Reported fish biomass (kg/ha) for different water body types across Europe, n = sample size (means and error bars derived by bootstrap calculation).

systems. Most data available refer to relative — rather than absolute — abundance, used for assessing stock trends rather than calculating absolute fish density. In the present analysis, fish biomass was partly estimated by expert judgement or was determined by standardised methods, mostly through statistical calculations. The 117 cases providing information on fish biomass include all eight water systems types, although, as in other analyses, the numbers of cases from opens seas and estuaries is small (Figure 9.8).

Generally speaking, fish biomass varies between seasons, years, sampling sites and between water body types. The biomass of a fish species is the result of recruitment size, mortality- and growth-rates, which are influenced by food and habitat characteristics or by abiotic parameters like water level changes, drought or nutrient content. From the scientific literature, the correlation between phosphorous content and fish biomass has been well documented for lakes (Hanson & Leggett 1982, Quiros 1990, Jeppesen *et al.* 1997). Eutrophication of many surface waters due to the discharge of untreated sewage waters has taken place in many, if not all, lowland areas in Western Europe. Especially after WW-2 the situation deteriorated, culminating in many countries around 1980. In the last decades the reverse trend has taken place in many European countries. This process of nutrient reduction has involved intense technical efforts to treat sewage and a shift to phosphate-free detergents, (Scheffer 1998). The practical effects of this trend are still the subject of research but the ‘environmental clean-up’ tends to result in a reduction of fish biomass, very often accompanied by a shift in species composition.

In this study, the reported fish biomass situation appears to be fairly similar for most water body types in Europe (Figure 9.8). However, the highest reported overall mean fish biomass values occur for fishponds and inland seas. These water types with higher fish biomass values correspond to those where Cormorant densities are also relatively high (see Figure 9.5), suggesting that the birds are attracted to systems holding a high density of fish.

9.5 Abundance and consumption of fish

Many experts provided extensive information on fish for the different cases collated into the Water Systems Database. The total number of fish species in a specific water systems was provided to demonstrate the range of biodiversity within European waters. The total number of fish species differs considerably between water systems types but also within them (Figure 9.9). Coastal waters and other generally large-scale areas (i.e. open sea, lagoons, estuaries and inland seas) have a higher diversity of fish species overall than do most freshwater systems. In estuaries, the number of fish species varies considerably between simply-structured (often small) areas that support few fish species and the larger, often more natural, areas like the Danube Delta with more than 120 fish species present (Figure 9.9). Large freshwater systems (e.g. large lakes and large rivers) have an intermediate number of fish species, whilst the smallest freshwaters (e.g. streams, reservoirs and fish ponds) contain only few fish species, chiefly reflecting unnatural situations, or even commercial monoculture of certain species.

In terms of the fish communities within different water systems, a

Laboratory work at RIZA, The Netherlands: identifying and measuring fish otoliths from Cormorant pellets provides data on the species and size of fish eaten by the birds. Photo courtesy of Florian Möllers.

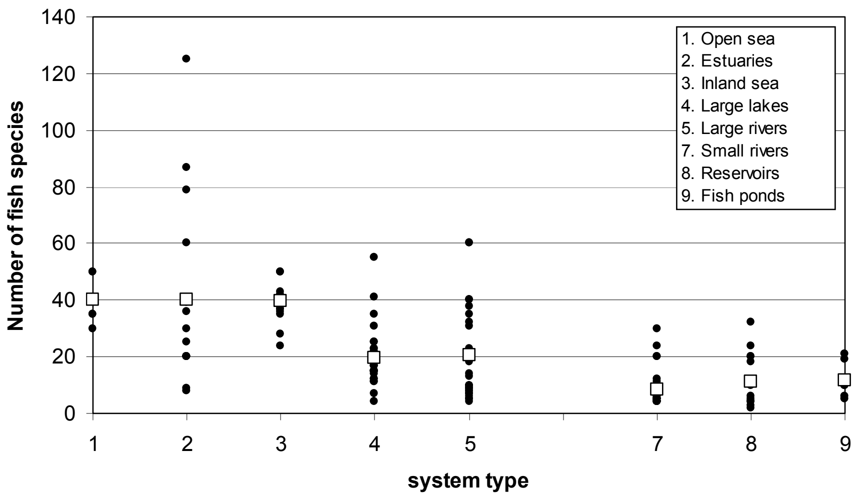


Figure 9.9 The reported number of fish species (and average) for different water body types across Europe. The average value for each system is indicated by the white square.

comparison was made between the ranking of the three most abundant fish species reported in each water body and the three most commonly reported fish species eaten by Cormorants at the same site. This comparison was meant to show the most 'important' fish species involved and their relationships with both Cormorants and water systems type.

In ranking the three most abundant and most commonly eaten fish, some 90 species were reported. This illustrates the diversity of water systems in the European context. All eleven most common species present, as reported for the Water Systems Database, occur in freshwater systems. This is partly a result of the greater diversity in salt and brackish waters compared to that in most freshwater systems.

If the most abundant fish species at specific locations and the fishes most commonly eaten by Cormorants in these same places are compared, a strikingly comparable pattern appears (Figure 9.10). The distribution of the most commonly reported fish species in this combined sample is not representative of the entire European situation because some water systems types are under- or over-represented. Nevertheless, the picture shows that only a few species of fish constitute the majority of the most commonly reported — both in terms of abundance in particular waters and also in their frequency in Cormorant diet at the same location. The general pattern thus indicates that the most common fish species in a particular water systems are also the most common Cormorant prey. Nonetheless Cormorants might be more selective for certain fish species if more detailed information on the availability of these fish to the birds were available. An important factor here is likely to be the size-distribution of the fish. Cormorants clearly feed primarily on the most abundant fish species and tend to eat smaller individuals (often young-of-the-year and/or juveniles). Larger fish are often too fast and thus evade capture, or are not numerous enough to be included as a significant part of Cormorant diet.

Finally, patterns of fish abundance and frequency in Cormorant diet were explored separately for different European water body types (Figure 9.11).

Open sea, inland seas, lagoons and estuaries are considered together here as 'coastal areas'. The distribution of the ten most

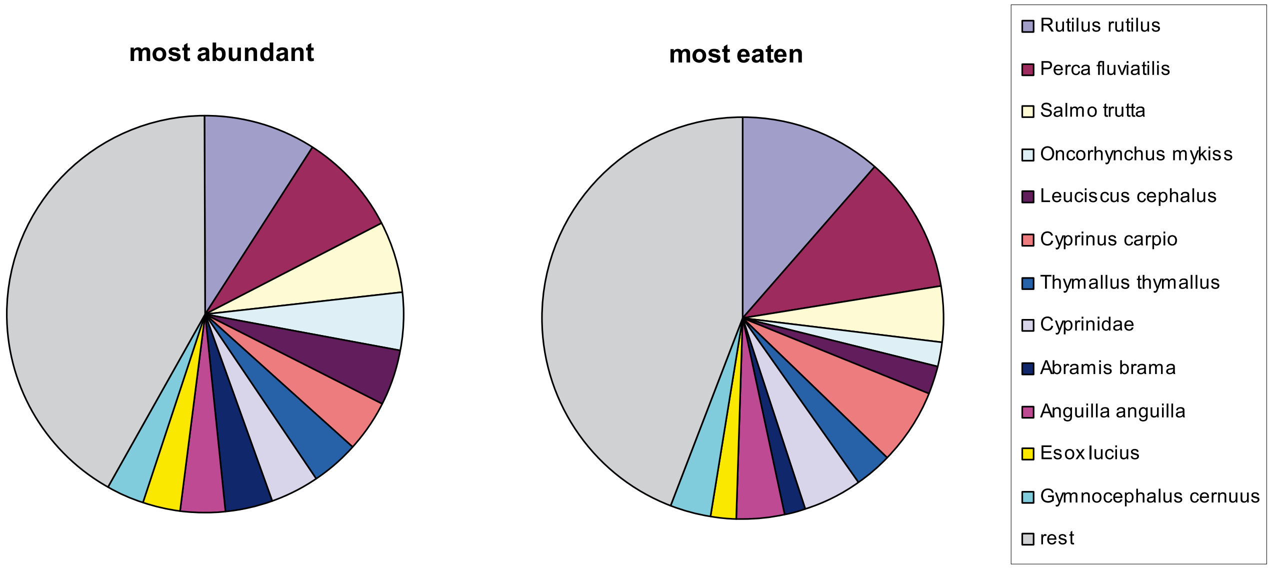


Figure 9.10 Frequencies of reported cases of fish species that are the most abundant (N = 465) and the most commonly eaten (N = 309) by Cormorants at locations included in the Water Systems Database.

abundant fish species in these coastal waters is rather even with no specific species dominating the community. This is thought to ultimately reflect the high diversity of coastal habitats that, in turn, support a large variety of fishes with no particularly dominant species overall. There is no clear relationship between the most abundant fish species and those most commonly eaten by Cormorants. The tendency appears to be that common near-bottom freshwater species like Roach (*Rutilus rutilus*, in inland seas and the Baltic for instance) and Ruffe (*Gymnocephalus cernuus*, inland seas) are eaten by Cormorants somewhat more frequently than their presumed abundance would indicate. The more pelagic species (that tend to live in the water column, often farther offshore) such as the Sprat (*Sprattus sprattus*), Smelt (*Osmerus eperlanus*) and Herring (*Clupea harengus*), are taken far less commonly; the same is true for most other, less abundant, species.

Large lakes are clearly dominated by Roach and Perch (*Perca fluviatilis*). These species are also the most commonly reported prey of Cormorants here. Other Cyprinids, Mullets (*Mugilidae*) and Whitefish (*Coregonus* spp.) are less abundant but tend to be eaten more often than expected from their presumed abundance. Species that are taken by Cormorants less frequently than their abundance would suggest are often predatory fish such as Pike (*Esox lucius*) and Pikeperch (*Sander lucioperca*) or larger species like Bream (*Abramis brama*).

The Cyprinids Chub (*Leuciscus cephalus*) and Roach dominate in large rivers. Experts provided data on the most commonly eaten species by Cormorants in only ten cases. This was insufficient to show a clear relationship with the most abundant species. However, although not drawn directly from the Water Systems Database, cyprinid species are often found to be the most important constituent of the fish fauna of larger rivers (see Govedic *et al*. 2002).

According to the available information provided through the inquiry, small rivers and streams are dominated by Salmonid species like Brown Trout (*Salmo trutta*), Rainbow Trout (*Oncorhynchus mykiss*) and by Grayling (*Thymallus thymallus*). Brown Trout and Grayling are often reported as being commonly taken Cormorant prey in these water systems. However, extensive Austrian pellet studies have shown that Cormorants in this habitat most commonly ate Nase (*Chondrostoma nasus*), Roach and Ruffe (Trauttmansdorff & Wassermann 1995). Similarly, extensive studies in Slovenia have shown the importance of Chub, Nase and Barbel (Govedic *et al*. 2002) in these small river habitats. Remarkably, these species did not occur in the top ten most abundant fish species reported from this habitat type in the present study and were seldom reported as being commonly eaten by Cormorants

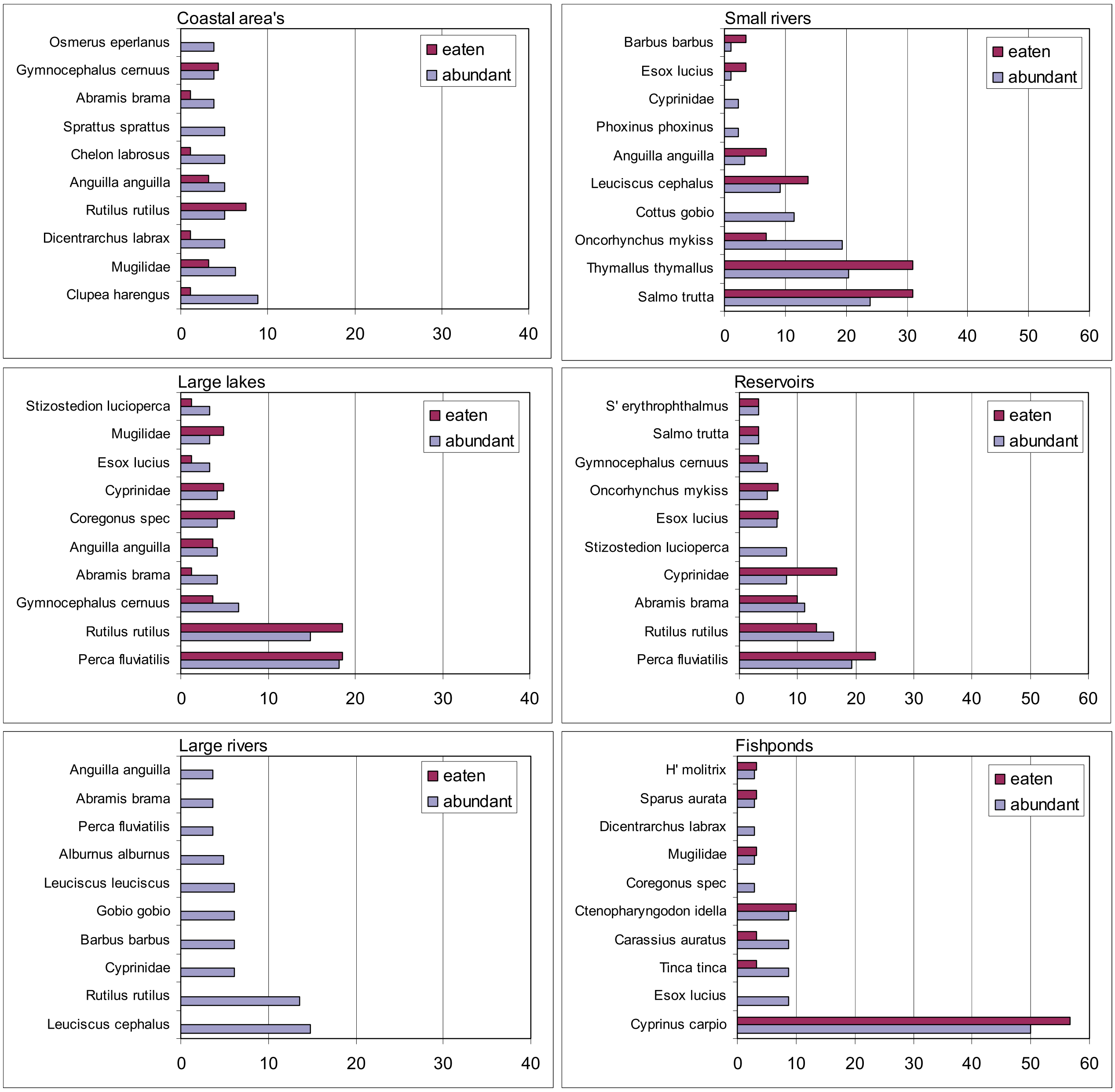


Figure 9.11 The distribution of fish species reported as being most abundant compared with those reported to be most commonly eaten by Cormorants presented for 6 different habitat/water system types across Europe. Open sea, inland sea and estuaries have been combined as 'coastal areas'. For large rivers, too few data were provided on the most commonly eaten species for data to be shown.

(in a Bulgarian small river Roach was reported as the second most common prey species and Chub was reported once each in German, Italian, Slovenian and Bulgarian small river cases). Hardly any information was available for the many endemic species of fish in the Balkan countries, central Romania, Bulgaria and Greece, neither with respect to their abundance nor to their prevalence in Cormorant diet. See chapter 12 for further discussion.

Perch tends to dominate the fish community of reservoirs, small lakes and sandpits, and Roach, Bream and several other Cyprinids are also reported as being abundant in this habitat type. Cormorants have a clear preference for Cyprinids in this habitat and, to a lesser extent, for Perch. Other, less common species are reported to be eaten by Cormorants as might be expected from their presumed abundance.

Fishponds in Europe are strongly dominated by Carp (*Cyprinus* *carpio*). This species, together with the introduced Grass Carp (*Ctenopharyngodon idella*), is eaten more commonly than might be expected from their abundance. Less commonly eaten species than might be expected are again the predatory fish such as Pike in freshwater systems and Sea Bass (*Dicentrarchus labrax*) in modified lagoon systems.

10 CORMORANT CONFLICTS

The rationale behind this exploration of 'Cormorant conflicts' is that knowledge of the spatial distribution and ecology of Cormorants and fish is basic to understanding of the occurrence of these conflicts, and may be of help in mitigating possible damage to fisheries interests caused by the birds. Furthermore, this exploration includes the most recent (i.e. up to 2007/08) information available to **INTERCAFE** participants in relation to the management actions taken against cormorants across Europe. Such actions being taken as a result of Cormorant-fishery conflicts, some of which are considered here. Generally, these management actions are also relevant to **INTERCAFE's** information on Cormorant population status and distribution (see chapter 6). Specifically, information is collated on six different management actions carried out across Europe. This more recent information on management actions allows comparison with similar, earlier information provided by Carss (2003: 106–108). Similarly some of the information here can be compared to the Cormorant status and distribution information presented earlier in chapter 6.

This chapter begins with a broad-brush approach based on conflict information provided to the Water Systems Database and found in the published literature. In chapter 11 we then examine site-specific local conflicts which occur in the case areas described in chapter 5.

10.1 Ecological conflicts: protected fish species and Cormorants

Cormorants are an important avian predator on fish stocks. In Europe, many fish species and aquatic habitats are preserved under the EU-Habitat Directive, as well as by national laws. Data for a large part of Europe (Figure 10.1) show the widespread distribution of a number of protected fish species under the EU's Habitat Directive, these data include material from Slovenia and Croatia collected through recent investigations (M. Govedič). Although this picture is far from complete, especially for the eastern European countries, general conclusions can be derived from the map. First, sites of major importance with respect to the presence of fish species occur in most European countries. However, at a regional scale, some focal areas are apparent, for example in areas where seven or more protected species occur at the level of five or more neighbouring 50 x 50 km grid cells. These areas comprise the River Elbe, Oder and the upper Rhine area in Germany, the lower Rhine area in The Netherlands, and some waters in Wales in the UK, major stretches along both the upper and lower River Loire in France, the Tagus and upper Guadiana basin in Spain, major parts of the Po river basin, areas in north east Austria, parts of upper Slovenia and Croatia, and rivers discharging into the Adriatic Sea.

At a European scale the area of northeast Austria and the water systems surrounding the upper part of the Adriatic Sea appear most important with respect to the diversity of protected freshwater fish species. This area probably extends further southeast into the Balkans but, due to the lack of grid-based inventory data in these countries, this situation remains unclear. In winter, Cormorants in Europe are distributed rather evenly across the array of available inland water habitats (see Figure 6.3). As the low-altitude larger river systems attract most Cormorants (see chapter 8), in a number of cases these are also areas holding the highest numbers of protected fish species. For example, the lower and upper Rhine area, the Loire, Tagus and Guadiana catchments share high Cormorant numbers (in regional group [A], see chapter 6) and a high presence of protected fish species, whilst in the Baltic/central European regional group (B), the most important fish conservation areas are in northeast Austria and the Po river catchment. The latter region is known as an important wintering area for Cormorants. Compared to the distribution maps of Cormorants (see chapter 6) there is no clear picture at all that Cormorants are attracted by areas of high fish species diversity. Any overlap in the areas mentioned

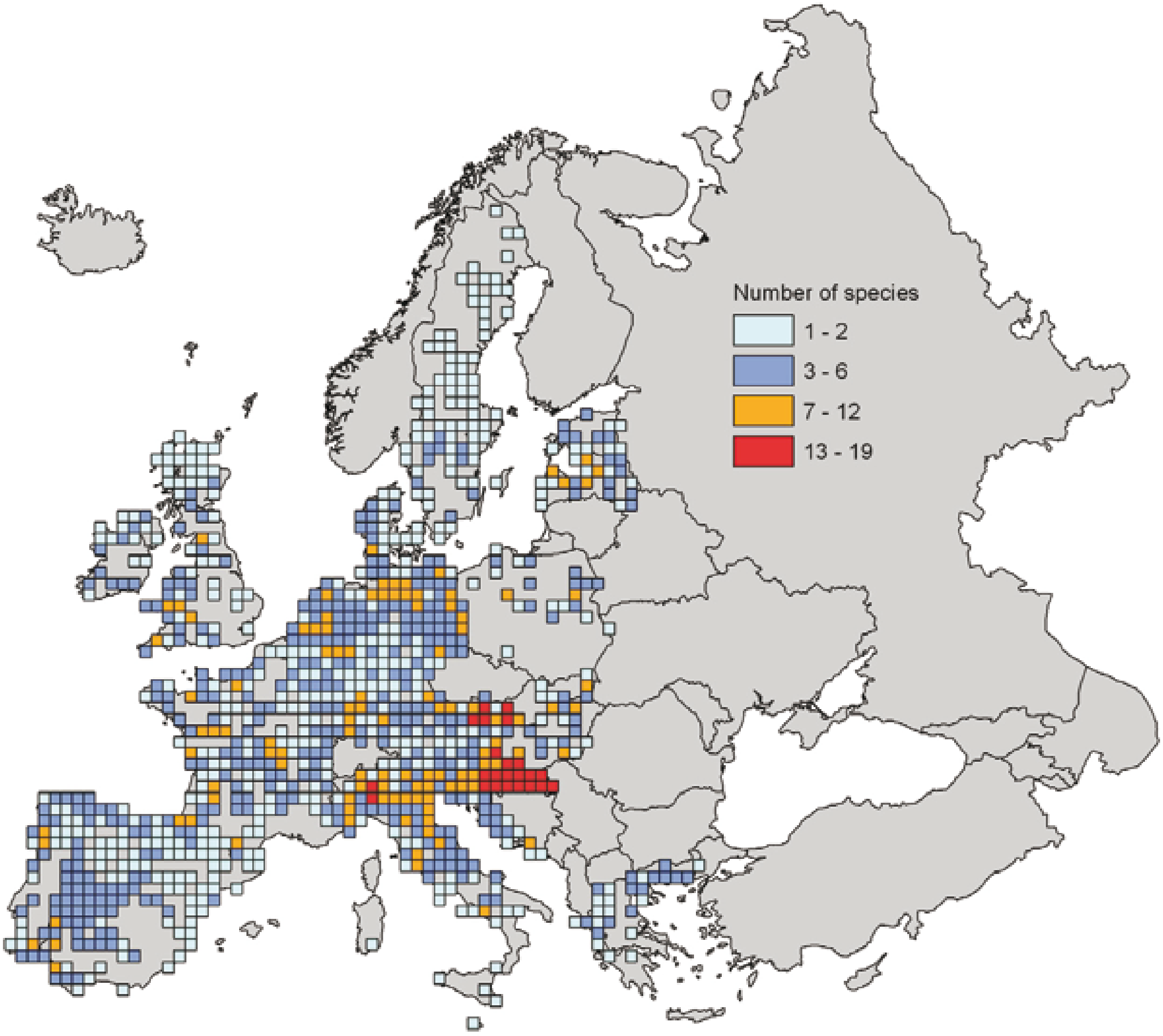


Figure 10.1 50 x 50 km grid cells showing the number of fish species listed under Annex II of the Habitat Directive. Data are from the Natura 2000 database. Note the fact that data for non-EU countries (e.g. Switzerland, Norway) are not presented and that for some countries (e.g. Czech Republic, Romania, parts of former Yugoslavia) data are currently unavailable.

above is probably due to factors other than the presence of diverse fish species. We may conclude, however, that Cormorants do show up in areas with a high number of fish species although this is probably not the specific reason for their appearance there.

10.2 Economic aspects: distribution of cases

Most 'important' conflict areas in each country in Europe were plotted on a map, using the standard 50 x 50 km grid (see chapter 8). The data from the REDCAFE Concerted Action were used and extended with recent information. Several conflicts were reported to us several times and so any duplicates were omitted. Thus the overall list of 438 cases (see Table 3.4) was condensed to 312 cases (Table 10.1). Countries ranged from 57 conflicts reported in Poland to 1 in Norway and analysis shows that the higher number of reported conflicts is associated with an increasing amount of small-scale areas. By identifying patterns in the distribution of conflict areas in Europe, it is possible to correlate the distribution of reported conflicts with environmental and socio-economic factors, as well as directly with Cormorant numbers.

As can be seen from Figures 10.2 and 10.3 (both show the same conflict data), the major conflict cases reported are not randomly distributed across Europe. Fewer conflicts are reported from the western part of the continent than are from the east. Some countries like Spain and Portugal (occupied

Table 10.1 Cormorant-fishery conflicts reported during the REDCAFE and INTERCAFE projects for different countries. Conflict areas are unique with respect to geographic location.

Country	Cases
Poland	57
Italy	32
Slovenia	26
Austria	20
Germany	20
Lithuania	17
Spain	14
Romania	13
France	13
Bulgaria	12
Portugal	11
UK	9
Finland	9
Sweden	9
Denmark	9
Latvia	8
Greece	6
Czech Republic	5
Georgia	5
Belgium	4
Estonia	3
Israel	3
Netherlands	3
Serbia	3
Norway	1

by wintering *sinensis* Cormorants), but also Norway (occupied year-round by *carbo* birds) have few reported conflict cases, whereas other countries (e.g. Italy, Austria, Slovenia, Baltic States) have a longer list of records. For the latter countries, Italy has both breeding and wintering Cormorants, Austria only wintering Cormorants, and the Baltic States predominantly have breeding Cormorants in the summer. Conflicts are thus not confined to a specific time of year (see also chapter 3 of Carss, 2003).

When compared to the distribution of larger areas of surface water, no straightforward association between this and the reported conflict locations is apparent. In the breeding period (Figure 10.2), reported conflicts include areas with larger areas of surface water like for instance in Poland (Mazurian Lakes), the Baltic States (coasts) and The Netherlands (Lake IJsselmeer). However, on the European scale, most Cormorant-fisheries conflicts are being reported in an area ranging roughly from the north east Baltic via Poland, the Czech Republic, Austria, and south east Germany to north eastern Italy and to central France. This area is most intensely used by Cormorants belonging to regional group (B) — the Baltic/Central European group — that is currently undergoing rapid expansion. Interestingly, the area roughly coincides with the main watershed through Europe that divides those river catchments discharging towards the North and Baltic Seas as well as to the Atlantic Ocean on one hand and towards the Adriatic, Mediterranean and Black Sea on the other.

When reported conflicts are compared to the distribution of main winter roosts, again no clear pattern is obvious. The majority of Cormorants winter in areas where relatively few conflicts are reported. More specifically, conflicts tend to be reported most at the edges of the geographical distribution of

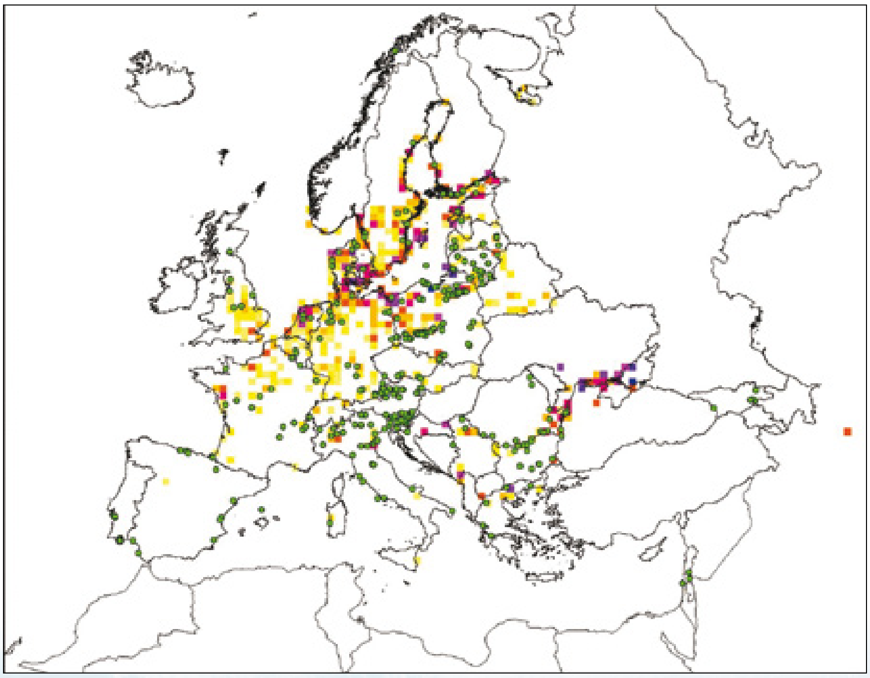


Figure 10.2 European Cormorant-fisheries conflicts (green dots) reported during the REDCAFE Concerted Action and through the INTERCAFE network project, in relation to the distribution of Cormorants during summer (grid cells 50*50km). Most of the conflict cases reported do not coincide with the core breeding areas (as indicated by red/purple grid cells).

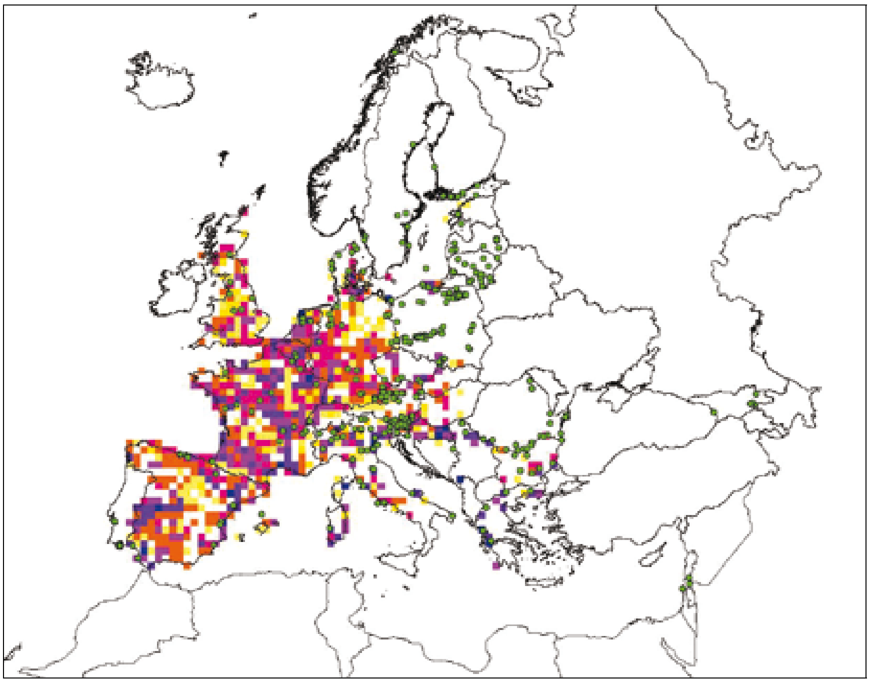


Figure 10.3 European Cormorant-fisheries conflicts (green dots) reported during the REDCAFE Concerted Action and through the INTERCAFE network project, in relation to the distribution of Cormorants during winter (grid cells 50*50 km). Most of the conflict cases reported do not coincide with the core wintering areas (as indicated by red/purple grid cells).

Cormorants. This may be either (i) a seasonal effect, as for instance when Cormorants migrate from one area to another, passing across areas where they (at most times) do not concentrate or (ii) a temporal effect in terms of areas that have become established by Cormorants only recently due to the species' continued range expansion.

Overall, using data from the area presented in Figure 10.3, reported cases of conflicts with Cormorants were not restricted to areas where winter densities of the birds were highest (Figure 10.4). Indeed, most conflict cases were reported in areas of intermediate densities of Cormorants in winter. At increasing Cormorant density (winter roost counts), the number of reported conflicts increases. However the lower proportions of reported conflicts are either for the lowest Cormorant densities or for the highest density classes. The latter finding is probably related to the fact that the highest density classes of Cormorants occur in lowland areas where fisheries' interests (and hence conflicts) are less prominent.

Many Cormorant-fishery conflicts are reported from the relatively small pre-Alpine region (see Figure 10.5). This is clearly an important area for further investigation. Here, a lot of different water body types are present within a short distance as fast running waters and small lakes at high altitudes merge into larger rivers and lakes. Cormorants migrate through this area to and from the Mediterranean and as well as there being wintering bird concentrations there mainly on the larger lakes and river systems. During periods of severe frost, the birds move out of such areas or use the more upstream parts of the small river sections. These tend to freeze later or not at all during frosty weather. It is this specific habit

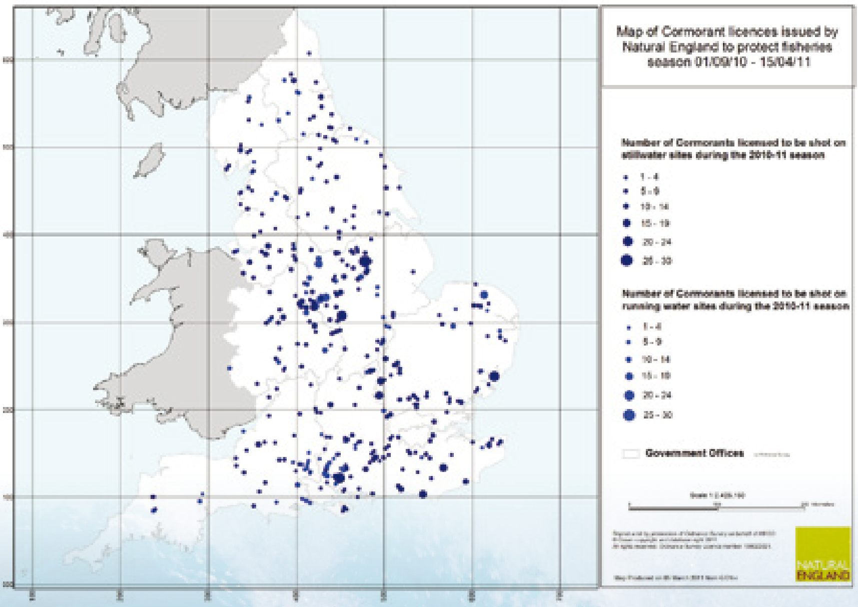


Figure 10.4 Map of the southern part of the UK showing sites in England where Cormorants were shot under licence, in order to mitigate a specific local problem.

Figure 10.5 Detail of map showing the distribution of reported conflict cases (green dots) for the area centring on the greater Alpine and sub-Alpine region in Europe. The 50*50 km grid squares depict Cormorant density in winter.

that causes most concern, as these are the waters holding the most vulnerable Salmonid and Grayling populations. As can be seen in Figure 10.5, the concentration of reported conflicts in the pre-Alpine region is not correlated to the presence of Cormorant roosts in winter. There was also no correlation with the presence of breeding colonies. Also, if compared to the distribution of protected fish species, the areas only partially overlap. For example, most reported cases of Cormorant damage to fisheries in Slovenia originate in areas other than those with the highest diversity of protected fish species. In the next chapter the cases of Slovenian and Austrian pre-Alpine rivers are further explored (see 11.5 and 11.6 respectively).

Conflicts differ with respect to their extent. The conflicts listed above comprise the major cases that have been mentioned and reported on a European scale. However, the effects of Cormorant predation are also invariably reported at regional or local scales. At a finer geographical scale, that of a single country or state, many small conflicts may occur. As an example, Figure 10.4 shows the number of licenses issued recently to kill Cormorants under derogation in part of the UK. The map gives an update showing the locations where licences to shoot Cormorants were issued in England over the most recently available licensing period (winter 2010–11). This indicates a pretty broad, countrywide distribution of 'conflicts', with concentrations in the south and the Midlands, and relatively few licences issued in the far southwest and East Anglia. Again, this distribution only partly reflects Cormorant distribution in winter, but will merely be influenced by the location and management of fishery sites. Most licences are issued on still waters (the majority being managed recreational fisheries, often with elevated fish stock densities) and these are often sited near centres of human population. The relatively low number of licences issued for East Anglia is remarkable, given the proximity to the continent and the known influx of wintering birds from continental areas, possibly related to the fact that this is a relatively rural area. A similar situation occurs in a country like France; here, many local conflicts have resulted in the acceptance of shooting for which licences are issued and over 30,000 birds are shot each winter (e.g. 31,000 in 2001/08 and up to 33,000 in 2009/10 from a permitted 'quota' of 41,800 birds). Licences for killing Cormorants are issued according to nationally agreed procedures, most often by specialist wildlife biologists, to ensure as consistent an approach as possible.

10.3 Management actions taken against cormorants at the 'European' scale

Earlier work by REDCAFE participants (Carss 2003: 103–130) provided information on management actions taken against Cormorants during 2001/02. This information was available for 25 countries: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden and the United Kingdom. During the work of the **INTERCAFE COST** Action it was possible to update this information for 2006/07 and also to incorporate information from an additional three countries: Croatia, Serbia and Slovakia. Wherever possible, information for these countries was also provided retrospectively for the period up to 2002 and so, for all countries, the two time periods (up to 2002, 2006/07) were broadly comparable.

Information is presented below, on a country-by-country basis, for all those countries participating in REDCAFE and/or **INTERCAFE** named on previous page. However, mindful of earlier comments (section 6.2) that, when considering Cormorant status and distribution it is vital to carefully define the specific area under consideration, information is also presented and discussed here on the basis of four geographically derived datasets. These relate to two 'politically-relevant' geographic areas and two 'biologically-relevant' ones (see below).

The basic 'management actions' dataset(s)

Specific information was collated on six different Cormorant management actions carried out across Europe. These are (1) the destruction and/or disturbance of breeding colonies, (2) the destruction of nests and/or their contents (often through the oiling or pricking of eggs to kill the embryos and prevent them hatching), (3) the killing of nestlings, (4) of non-breeding birds (adults and immatures) and (5) of adult breeding birds, and (6) the destruction and/or disturbance of night roosts. This information is presented for each of the 29 countries participating in **INTERCAFE** (Table 10.1 parts I-III).

This information can be further collated and summarised in relation to two 'politically-relevant' areas and two 'biologically-relevant' ones. The 'politically-relevant' areas are (a) all 29 countries participating in REDCAFE/ **INTERCAFE** and (b) EU-27 countries (all except Cyprus, Hungary, Luxembourg, Malta) whilst the two 'biologially-relevant' areas are (c) countries in Region A (see Figure 6.1 but here excluding Iceland, Luxembourg, Morocco, Algeria, Tunisia) and (d) countries in Region B (see Figure 6.1 but here excluding Kaliningrad, Hungary, Albania, Macedonia, Bosnia & Herzegovina).

The spraying of Cormorant eggs in ground-breeding colonies in Denmark is a management tool to reduce the number of offspring produced.
Photo courtesy of Florian Möllers.

Information on these four areas is presented in Table 10.2.

Specific management actions

This section is an exploration of some of the figures presented in Table 10.2, and the information discussed from 'earlier years' (specifically 1990-2002) was originally collated during the EU-funded REDCAFE Concerted Action and was originally presented in Carss (2003: 106–108).

The information collated here was derived both from published sources and from the informed estimates of the various experts involved in the **INTERCAFE** Action. As such, these estimates should not be regarded as an authoritative, official, nor even a necessarily completely accurate estimate. Nevertheless, they provide the most thorough information available (in both specific detail and geographical spread). Thus **INTERCAFE's** most recent data (mainly relating to information for the year 2006 or the winter 2006/07) is thought to provide a reasonable basis for comparison with the REDCAFE data (compiled in a similar way, mostly for 2001/02) and a means for indicating possible trends. Where possible the information on the effects of management actions is compared with that of cormorant status and distribution given earlier in chapter 6.

(i) Breeding colonies destroyed or disturbed

In earlier years (1990–2002), 50 Cormorant breeding colonies were reported to have been destroyed or disturbed each year in the 28 countries reviewed here. More recent data suggest such actions have increased somewhat in the countries surveyed, with a current

Table 10.1 Information on the management actions taken against Cormorants in each of the 28 countries participating in INTERCAFE. Countries are grouped according to whether they either fall into the 'biologically-relevant' geographic regions A or B (parts I and II of Table, respectively) as described in section 6.1 or whether they occur in the Middle East (i.e Israel, part III of Table).

(I) Region A countries	Time period	No. of breeding colonies destroyed or disturbed	No. of nests destroyed	No. of nestlings killed	No. of birds (adults & immatures) killed in the non-breeding season	No. of breeding adults killed	No. of night roosts destroyed or disturbed
1. Belgium	2001/02 2006/07	0 0	0 0	0 0	0 ca. 100	0 0	2–3 Yes
2. Denmark	1994–2002 2006	10 23	3,000 6,600[1]	0 0	2,700 3,700[2]	400 0	1 1
3. France	2001/02 2006/07	2 1	0 0	0 0	20,000 30,861	0	200 The majority
4. Ireland	2001/02 2006/07	0 0	0 0	0 0	<20 <20	<20 <20	0 0
5. Netherlands	2001/02 2006/07	0 0	0 0	0 0	0 0	0 0	0 0
6. Norway[3]	2001/02 2006/07	0 0	0 0	0 0	10,000 10,000	0 0	0 0
7. Portugal	2001/02 2006/07	0 n/a	0 n/a	0 n/a	0 0	0 n/a	0 0
8. Spain	2001/02 2006/07	0 0	0 0	0 0	0 >1,000	0 0	0 0
9. Switzerland	2001/02 2006/07	0 0	0 0	0 0	1,300 1,000	0 0	Yes 0
10a. UK — England & Wales	2001/02 2005/06	0 0	0 0	0 0	200–250 1,388	0 0	<20 0
10b. UK — Scotland	1995–2002 2006/07	0 0	0 0	0 0	300 90	0 0	0 0

(2006/07) estimate of at least 63 colonies affected. Most of these colonies were in Sweden (a few tens) and Denmark (23). Smaller numbers of colonies were destroyed or disturbed in Austria (1), Estonia (5), Finland (3), France (1), Germany (6), and Lithuania (4).

(ii) Nests destroyed

In 2001/02 some 7,094–8,094 Cormorant nests were reported to have been destroyed annually across the 28 countries, including nests where eggs were oiled. This increased to between 9,845 and 10,845 nests in the most recent (2006/07) estimates, mainly as a consequence of egg oiling. Such actions mainly occured in Denmark (6,600 nests) and Sweden (2,000 to 3,000 nests), with smaller numbers in Estonia (650), Finland (403) and Germany (192). Nest destruction activities are thus concentrated in particular countries, and so, overall, this management action affects relatively low proportions of active nests across 'Europe'.

In terms of the EU-27 political area, data are available for 23 of these countries and they can be compared with the Cormorant breeding population figures given in section 6.2 which refer to the

Table 10.1 *Continued.*

(II) Region B countries	Time period	No. of breeding colonies destroyed or disturbed	No. of nests destroyed	No. of nestlings killed	No. of birds (adults & immatures) killed in the non-breeding season	No. of breeding adults killed	No. of night roosts destroyed or disturbed
11. Austria	1995–2002 2000–2006/07	0 1[4]	0 0[4]	0 0[4]	>450 400–450	0 0	>4 >6
12. Bulgaria	1998–2002 2006/07	2 0	81 0	0 0	>1,000 <1,000	Yes <100	5 2–3
13. Croatia[5]	2001/02 2006/07	6 0	n/a 0	n/a 0	n/a >1,000	n/a 0	n/a n/a
14. Czech Republic	1990–2002 2004–2006	2 0	0 0	0 0	1,600–2,800 2,100–3,100	0 Few	Yes Yes
15. Estonia	1997–2001 2006	7 5	1,800 650	50–100 0	102 290	0 0	0 0
16. Finland	2001/02 2007	0 3	0 403	0 0	0 0	0 0	0 0
17. Germany	1995–2002 2006/07	9 6	113 192	500 0	7,131 ca. 15,105	78 0	Yes Yes
18. Greece	2001/02 2007/08[6]	1 0	0 0	>50 0	250–350 5,000–6,000	0 0	1 n/a
19. Italy	2001/02 2004/05	5 0	<100 0	0 0	2,000–2,500 4,500–5,000	<100 <550	12 n/a
20. Latvia	1995–2002 2006/07	0 0	0 0	0 0	>200 137	0 0	0 0
21. Lithuania	2001/02 2005–2008[7]	1 4	0 0	0 0	1,000 1,009	0 0	0 0
22. Poland	2001/02 2006/07	0 0	0 0	0 0	2,100–2,300 2,000–2,600	0 0	0 0
23. Romania[8]	2001/02 2006/07	0 n/a	0 n/a	0 n/a	>200 n/a	0 n/a	0 n/a
24. Serbia	2001/02 2006/07	n/a 0	n/a 0	n/a 0	n/a 20–30	n/a 5-10	n/a 0
25. Slovakia	2001/02 2006/07	n/a 0	n/a 0	n/a 0	n/a >100	n/a 0	n/a 0
26. Slovenia	2001/02 2006/07	0 0	0 0	0 0	>200 200[9]	0 0	0 0
27. Sweden	2000 2006/07	ca. 5[10] 20[11]	? <2,000–3,000[12]	? 0	1,000 <3,500	3,000 <3,500	No No

Table 10.1 *Continued.*

(III) Middle East	Time period	No. of breeding colonies destroyed or disturbed	No. of nests destroyed	No. of nestlings killed	No. of birds (adults & immatures) killed in the non-breeding season	No. of breeding adults killed	No. of night roosts destroyed or disturbed
28. Israel	2001/02 2006/07	0 0	0 0	0 0	200 2,000	0 0	2 2

1. Mostly oiling of eggs (this is the case for 89% of the nests destroyed).
2. Figure refers to numbers of birds killed in 2005 non-breeding season.
3. P.c.carbo birds only in Norway.
4. There were two breeding colonies in Austria in 2007: partial tree-cuting in one colony to reduce nest numbers and breeding pairs.
5. Colonies on five fishponds (Donji Miholjac, Jelas, Nasice, Grudnjak, Koncanica) were completely destroyed in the 1980's. Breeeding adults and nestlings in the nest were killed at the Kopacki rit colony in 1989 and there was a 50% reduction in breeding pairs in the following year. There is no procedure for reporting bird numbers killed at fishponds.
6. Numbers are estimated form information provided by fishermen and biologists. All cormorants are illegally shot.
7. Numbers given are the average for the period 2005–2007.
8. Numbers for 2001/02 refer to the Danube Delta area only.
9. The official figure is 23: the number given is a best estimate
10. In total, 63 colonies are known to have been disturbed in the twelve years between 1985–2000 — giving an annual figure of just over 5 colonies. Disturbed colonies ranged in size from very small to quite large and only in a few cases of distrubance was complete breeding failure reported.
11. The number given is a best estimate, the true figure is unknown. Illegal disturbance takes place in a number of colonies every year but it is probable that this only occasionally results in abandonment or complete breeding failure.
12. In 2007 for the whole of Sweden, egg-pricking was undertaken on 10–15,000 eggs, whilst it is impossible to state exactly how many nests were affected, it probably corresponds to the figure given of 2–3,000 nests. Large egg-pricking campaigns have taken place for many years along the coast of Småland and, in recent years, also in the Stockholm archipelago. The practice also takes place along the coast in the province of Östergötland. Up to around 10,000 eggs were pricked in Småland in one season but the figure in 2007 was only 960 eggs. Egg-pricking was intense in the Stockholm archipelago in 2007 (about 8,000 eggs) but was almost zero the following year (for some reason people did not apply to do it in 2008).

EU-27 region plus Norway and Switzerland. Apparently no nest destruction took place in either of these countries and so, for this 'EU-27 plus' area, the best estimate is of some 9,845–10,845 nests destroyed in 2006/07. This compares to an estimated breeding total, for the same area in 2006, of approximately 284,500 pairs of Cormorants. Assuming each pair of birds is associated with a single nest, implies that this geographic area contained around 142,250 nests. Current information for management actions, suggesting about 10,845 nests destroyed here in 2006/07, represented perhaps 7.6% of active nests overall in 'EU-27 plus'.

Similar comparisons for biologically relevant regions A and B in 2006 (see Table 6.1) suggest that about 5% and 2–3% of active nests were destroyed annually in each region, respectively.

(iii) Nestlings killed

About 600 to 700 Cormorant nestlings were reported to have been killed annually up to 2002, mainly in Germany (500). No killing of nestling Cormorants in Europe was reported to **INTERCAFE** (2006/07), and the shooting of nestlings in Germany has ceased.

(iv) Adult and immature birds killed in the non-breeding season

Up to 2002, between 51,953 and 54,003 adult Cormorants (including immature birds in their first winter and older ones) were reportedly shot annually as control measures. This figure included 10,000 birds of the 'Atlantic' race (*Phalacrocorax carbo carbo*) hunted legally in Norway. The remaining 41,953 to 44,003 Cormorants thus mostly comprised the 'Continental' race (*P. c. sinensis*). In the more recent estimates (2006/07), these numbers increased to 86,520–89,680 birds, again including about 10,000 '*carbo*' birds hunted legally in Norway. As in the earlier period, most Cormorants were shot in France (30,861 in 2006/07). Other countries where relatively large

Table 10.2 Summary information on the management actions taken against Cormorants in the 29 countries participating in INTERCAFE, summarised for four geographic areas (a-d). Note that these geographic areas are not necessarily mutually exclusive (for full details see text).

* The figures in these three columns are considered to be best estimates, ** The figures in these three columns are considered to be under-estimates
1. Includes 2005/06 information for UK - England & Wales, which also applies to rows (a) and (b).
2. Includes 2000/07 information for Austria, 2004–2006 for the Czech Republic, 2006 for Estonia, 2007 for Finland, 2007/08 for Greece, 2004/05 for Italy, and 2005/08 for Lithuania, which also applies to rows (a) and (b).

Totals for 4 different areas of Europe	Time period	No. of breeding colonies destroyed or disturbed*	No. of nests destroyed	No. of nestlings killed	No. of birds (adults & immatures) killed in the non-breeding season	No. of breeding adults killed	No. of night roosts destroyed or disturbed
(a) All 28 INTERCAFE countries	Up to 2002	50	7,094–8,094	600–700	51,953–54,003	3,598	247–248
	2006/07	63	9,845–10,845	0	86,520–89,680	4,175–4,180	509–510
(b) EU-27	Up to 2002	44	7,094–8,094	600–700	40,453–42,503	3,598	245–246
	2006/07	63	9,845–10,845	0	72,490–75,650	4,165–4,175	507–508
(c) Region A	Up to 2002	12	3,000 6,600	0	34,520–34,570	420	223–224
	2006/07[1]	24		0	48,159	20	501
(d) Region B	Up to 2002	38	4,094–5,094	600–700	17,233–19,233	3,178	22
	2006/07[2]	39	3,245–4,245	0	36,361–39,521	4,155–4,160	8–9

numbers of 'adult' Cormorants have been shot in recent years (mainly data for 2006/07) are: Bulgaria (<1,000), Croatia (>1,000), Czech Republic (2,100–3,100), Denmark (3,700), Germany (15,105), Greece (5,000–6,000), Israel (2,000), Italy (4,500–5,000), Lithuania (1,009), Poland (2,000–2,600), Spain (>1,000), Sweden (>3,500), Switzerland (1,000), and UK–England & Wales (1,400).

Killing birds (adults, first-winter and older immatures) during the non-breeding season is thus a fairly widespread management action across Europe.

For the biologically relevant regions A and B in January 2003 (the first — and to date — only coordinated count at the continental scale, see Table 6.2), the most valid comparison (given the different time periods for which data are available) is, perhaps, with the numbers of Cormorants killed outside the breeding season up to 2002. During this time period the available information suggest that killed birds represented about 10% of the numbers of Cormorants estimated for region A in the winter of 2003 — very similar to the corresponding proportion for region B which was 8–9% of the estimated number of wintering Cormorants.

Comparing the estimated numbers of Cormorants killed in 2006/07 with the winter count of 2003 (probably a less valid comparison because wintering numbers may well have increased between 2003 and 2006/07) for regions A and B gives proportions of the winter population killed under management actions of 14% and 17–18%, respectively.

(v) Breeding adults killed

More than 3,598 adult Cormorants were reported to have been killed annually during the breeding season (April to September) for years up to 2002. For the more recent estimate, this figure has increased to at least 4,175–4,180 birds, with most again being killed in Sweden (<3,500) and Italy (<550).

(vi) Night roosts destroyed or disturbed

Although Cormorants are known to be disturbed and shot at night roosts in several countries, no reliable numbers have been available for either the REDCAFE COST Action or the more recent **INTERCAFE** investigation. Nevertheless, the reported numbers of night roosts destroyed or disturbed annually has increased from >248 for the countries covered by REDCAFE to more than 500 in the present study. As before, such actions are believed to take place mostly in France where a large proportion of the known 869 roosts in the country are believed to be affected. Estimates for other countries were relatively small.

Whilst not directly comparable, section 6.3 mentions the 2,500 roosts which formed part of the winter 2003 pan-European Cormorant count. Acknowledging that this number is almost certainly an underestimate, the available figure of at least 500 roosts experiencing destruction or disturbance represents nevertheless 20% of this figure.

11 CASE STUDIES OF CONFLICTS: ECOLOGICAL ASPECTS AT A LOCAL LEVEL

The ecological background of several 'local' Cormorant-fisheries conflicts was explored during some **INTERCAFE** meetings. Intensive contacts with local stakeholders here allowed the situation and environment of the conflicts to be put into some sort of ecological context. Given the time available for this (maximum three days in Case Study meetings), the results were useful so as to describe the major patterns. As a result, explorations tended to focus on a specific important ecological aspect related to each case but from which insight could be applied to other water systems throughout Europe. Needless to say, according to the different settings and attendance by local stakeholders at such meetings, the ecological elements explored varied according to the input. As such, the information presented here is very much input-oriented (i.e 'bottom-up') and is therefore considered a reflection of the regional or local situation. We have tried to highlight the specific issues that were derived from the field by local experts. By putting the conflict into the context of the regional ecological situation and possible shifts therein, this was supposed to help to untangle the problem. This section discusses the outcome of these explorations at a regional or local level, again arranged by water systems type and by level of habitat scale: Gulf of Finland (coastal seas), Lake IJsselmeer and Vistula Lagoon (inland seas), Po Delta (estuaries), Austrian and Slovenian rivers (small rivers), Saxony, South Bohemia and Hula & Bet Shean Valleys (complex small scale water bodies with fish pond areas).

11.1 Gulf of Finland (category: open sea)

Cormorants are strongly increasing (numerically) and spreading (geographically) in this part of Europe, mainly during the spring and summer months. The area is not typical wintering habitat

Cormorant colony on one of the many islets in the eastern Baltic, Finland.
Photo courtesy of Stef van Rijn.

as many shallow parts of the Baltic Sea freeze over and fish retreat toward deeper water as temperatures fall. The concurrent negative trend in catches of commercial fish species is regarded as a direct consequence of the increasing Cormorant population and, locally, measures are taken to reduce the population (Timo Asanti pers. comm.).

The role that Cormorants play as a fish predator in this region does not point to it being a major threat to the fish populations here, at least not according to recent investigations (Lehikoinen 2006, van Eerden *et al*. 2007). Food items recorded in three colonies in Estonia and three in Finland in 2007 comprised predominantly non-commercial prey species.

Although extended research is needed to cover a greater time span and to indicate seasonal patterns over a larger geographical area, the picture is that the majority of fish taken are bottom-dwelling Eelpout (*Zoarces viviparus*), Butterfish (*Pholis gunnellus*), Gobies (*Cottus* spp.) and Sculpins (*Myoxocephalus* spp.), augmented with Sprat (*Sprattus sprattus*), Herring (*Clupea harengus*) and, locally, Roach (*Rutilus rutilus*). It is hypothesised that the Cormorant has reacted to a major environmental shift in the Baltic, which was first induced by environmental changes (less saline water entering from the west), reinforced by human action through the over-fishing of stocks of large predatory fish, as well as a concurrent increase in the nutrient load. All three factors have a positive effect on the abundance (and availability) of the small sedentary brackish and freshwater fish species, which in turn provide ideal foraging conditions for Cormorants.

This wider, longer-term ecological perspective shows the Cormorant-fisheries conflict in a different light to that of simply Cormorants having direct impact on fisheries. This complex situation urgently requires validation by extended research. Nevertheless, the conclusion is unavoidable — that the Cormorant prey choice merely reflects the fish availability in these waters, rather than being the result of selective hunting and foraging by the birds themselves. Thus in the Gulf of Finland, Cormorants can be considered to be responding to drastic environmental changes, some at a very large-scale and occurring over a long time. An understanding of such changes is clearly necessary to put the Cormorant issue into ecological context. The next two cases share some similarities with the Gulf of Finland situation, exploring in more detail the effects of nutrient enrichment and intensive commercial fisheries on fish community structure in large shallow waters.

11.2 Lake IJsselmeer and Markermeer, The Netherlands (category: inland sea)

Cormorants are considered a strong competitor of the commercial fisheries in the Lake IJsselmeer area by the local fishermen. There are indications of potential competition for Perch (*Perca fluviatilis*) but, given the heavy fishery pressure and correspondingly low stocks, this is much less likely for Eel (*Anguilla anguilla*) and Pikeperch (*Sander lucioperca*). However, the stock assessments show large numbers of young predatory fish which do not seem to enter the population. Most of the 'evidence' for losses of commercially important fish stocks due to Cormorant predation in these large systems is still based on indirect observations and calculations. In a recent study, extrapolated data from other, smaller-scaled water bodies were used to demonstrate the effect of Cormorant predation on the yield of Pikeperch (Witteveen & Bos 2008). These authors hypothesise a severe predation pressure by Cormorants on young Pikeperch as they concentrate in deeper waters in autumn and winter. Selective hunting would exterminate the shoals and aggregations of young fish. Current research on the food of the Cormorant outside the breeding period in the IJsselmeer area itself is now underway to elucidate the situation. Another possibility for this loss is the management of discharge water from the lake to the Waddenzee. It has been shown that in a nine month period over 1,000 tonnes of freshwater fish end up in the Waddenzee due to this massive discharge event at low tides. This corresponds to 50% of the estimated gross production of 0+ fish (i.e. young-of-the-year), being roughly 10 kg/ha (Witteveen & Bos 2009). The fish that have no cue as to what direction they are taken by the current are washed out and cannot return to the lake. Except for Smelt, most other species die because of salt stress. Again, Cormorants, but also mergansers, gulls and terns exploit this food source which is mainly the result of the lack of a salinity gradient towards the open sea.

The key ecological perspective here is that, on the other hand, over-fishing in these lakes is plausibly the cause of a relatively large proportion of small fish there. These are mainly Ruffe (*Gymnocephalus cernuus*), a non-commercial species that now constitutes up to 70% of Cormorant diet (in terms of biomass). The conclusion of a long-term study into the issue is that over-fishing has in fact altered fish community structure to favour both these abundant small fishes and, consequently, provide increased foraging opportunities for Cormorants (van Rijn & van Eerden 2002). It was concluded that Cormorants were not selective in the prey they took and that

Social fishing by Cormorants: an adaptation for foraging in turbid waters (Lake IJsselmeer). Photo courtesy of Mervyn Roos.

the abundance and community structure of fish species (and also their length-frequency distribution) in the lakes are largely reflected in the birds' diet in similar proportions.

Ecologically, the influence of turbid water is also important with respect to the observed levels of Cormorant predation. Cormorants always prefer to forage in waters with an intermediate underwater clarity of 0.4–0.8 m Secchi depth and turbidity is therefore considered important with respect to the predation levels that the birds can achieve. Lake IJsselmeer has a clear water phase in April and May, caused by zooplankton grazing on green algae. Before and after this period, turbidity is mainly caused by algae (diatoms and blue greens, respectively). This is in strong contrast with the situation in Lake Markermeer (separated by a dike from the northern part since 1975) that is turbid throughout the year because of erosion of its muddy clay bottom. In the breeding season, Cormorants mainly feed in Lake IJsselmeer and only forage in Lake Markermeer on days with little wind and, consequently, less turbid water. During periods of strong winds, the birds invariably choose to forage in sheltered (less turbid) waters of IJsselmeer.

The annual consumption of fish by Cormorants in the IJsselmeer area has been estimated at about 10 kg/ha/year (Van Rijn & Van Eerden 2002). This was considered the maximum possible exploitation for the current situation on this lake under 'natural' conditions (of current fish biomass and water turbidity). There may be a possible effect of Cormorant predation on commercially harvestable fish stocks of Perch but this is unlikely for Eel, Pikeperch and Smelt. The natural mortality of fish has not been measured under natural conditions and so the estimated consumption of fish by Cormorants cannot simply be related to the yield taken by fishermen in later years. Assumptions about natural fish mortality, in relation to the effect that Cormorants may have, play a central role in the outcome of the models applied to this complex biological system (van Dam *et al*. 1995). As long as the question of additive versus compensatory mortality levels in fish is unresolved, this remains the key missing element for demonstrating whether there is a significant Cormorant predation effect or not. Essentially this question is: does predation by Cormorants increase overall fish mortality (i.e. 'additive' mortality) or would the individuals eaten by Cormorants merely have died from other causes had they not been predated (i.e. 'compensatory' mortality), thus improving the conditions for those uneaten fish by providing less competition for food, space and other resources.

Consumption of large amounts of Ruffe by Cormorants may even have a positive effect on the food situation for Eel. Recent over-fishing of large Bream (*Abramis brama*) in the system has caused further advantages (feeding opportunities) for Ruffe because both species feed on midge (*Chironomidae*) larvae on the lake bottom. Over-fishing has at least an effect on fish size, shifting it towards a length frequency with much smaller fishes present than would be the case under natural conditions. This too has a positive effect on the exploitation possibilities of Cormorants. High numbers of Cormorants can thus be explained from an ecological perspective by the highly eutrophicated status of the system, combined with the situation of over-fishing by commercial fishermen. For water and fisheries' managers this example demonstrates the complexity of the situation and the peculiar position that Cormorants have in these modified waters. Cormorants typically adapt to the man-induced changes and easily use obstructions such as sluices, dams, and locks which hamper the passage and movement of fish. The altered fish-species composition caused by the heavy fishing of commercial fisheries is reflected in a shift in the diet of Cormorants. This ecological perspective also bears parallels to that explored in the Vistula Lagoon, Poland.

11.3 The Vistula Lagoon, Poland (category: inland sea)

Local fishermen generally consider Cormorants to be the main cause of reduced fish landings in the Lagoon, believing that the birds can reduce yields of valuable commercial fish species. However, some local fishermen have indicated that over-fishing is actually the main cause of the reduced sustainability of the fishery. Thus, this conflict between fishermen and Cormorants has again to be considered within a wider socio-economic and ecological context. Nevertheless, the key ecological perspective here is not that Cormorants are driving the fisheries system and are responsible for its changed status but the reverse — that the birds are responding to wide-scale ecological changes, in this case overfishing — which has lead to a super abundance of small fishes in the Lagoon. Cormorants here are also accused of killing the trees in which they breed through guano deposition and by the removal of

Measuring Cormorant eggs at the Kąty Rybackie colony, Poland, one of the largest colonies in Europe. Photo courtesy of Paolo Volponi.

small branches for nest building. While the local comorant colony expands and moves year after year, the actual area of destroyed forest in the Kąty Rybackie Reserve increases annually.

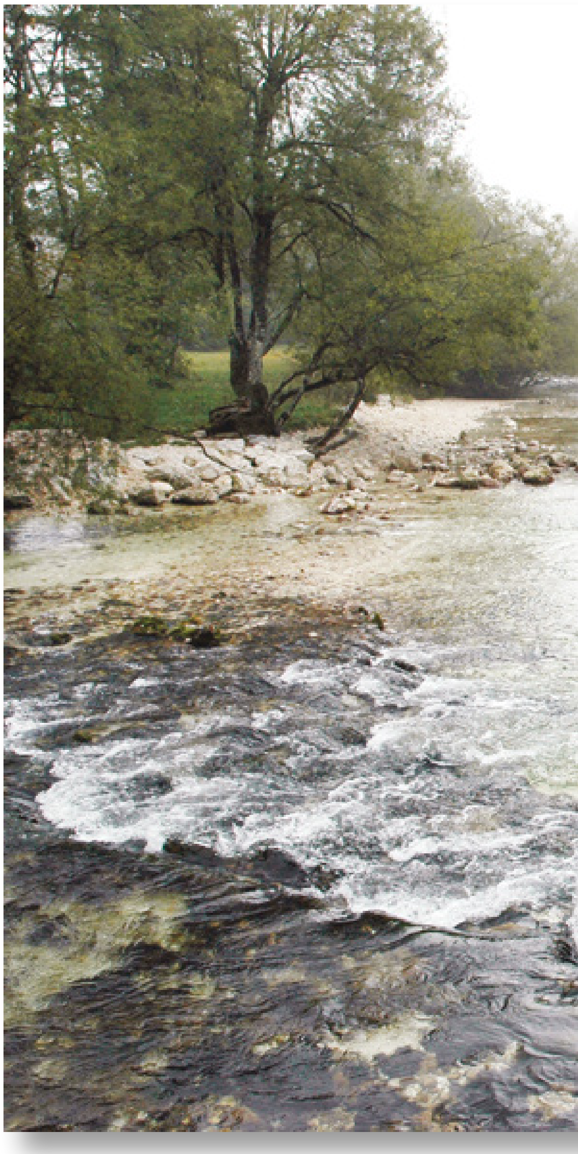
It is estimated that a total of 2,200–3,100 tonnes of small fish are removed each year from the Lagoon, commercial landings and Cormorant predation accounting for about 1,484–2,267 tonnes and 712–816 tonnes, respectively (Stempniewicz *et al*. 2003a). Commercial fish catches have declined considerably in the last 30 years, except for those of Herring. However, Cormorants generally select smaller fish than those caught by fishermen. Indeed, due both to their small size and species composition, the fish species taken by Cormorants have been found to be of little economic value. Cormorants are believed to have a positive effect on the Lagoon's fish community by reducing dominant species, such as Ruffe, while the negative impact is largely considered to be related to predation on Eel and young Pikeperch, Atlantic Salmon (*Salmo salar*) and Sea Trout (*S. trutta*, Martyniak *et al*. 1997, 2003).

In summary, for these large water systems the prognosis for the future very much depends on the implementation of measures to reduce over-fishing by commercial fisheries. Considerable reduction in overall human fishing pressure would probably reduce the Cormorant population because the number of small fish (both species and size-range) would decline in relation to an increased stock of large, predatory fish.

11.4 Po Delta (category: complex estuary and lagoon system)

The Po Delta is a major area for Cormorants in Italy as well as for commercial fisheries and *'vallicoltura'*, a traditional form of low-tech aquaculture consisting of specific lagoon management and extensive fish production (Ardizzone *et al*. 1988). Commercial fishing is carried out on a seasonal basis using fyke nets and gill nets in open bays and river estuaries, whilst about 30 different wetlands (*valli*) ranging between 250–6,500 hectares are managed for vallicoltura. Both in open bays and *valli*, fish catches show wide annual and site-to-site fluctuations, ranging between 70–112 and 11–84 kg/ha/year, respectively (Volponi 1997). Cormorant predation here has been estimated at between 5–10 kg/ha/year (Volponi & Rossi 1995).

Cormorants forage opportunistically in all available habitats but feed more regularly and intensively in the fishing-*valli* in late autumn and winter in particular — this also being the main fishing and fish-stocking period (Boldreghini *et al*. 1997) and fish availability and predictability is higher here than in adjacent river and open coastal waters. This is perhaps the key ecological perspective in this situation — that birds visit the fishing *valli* seasonally during the migration and wintering periods, coincidentally the time when the fish there are most vulnerable. Further important ecological issues relate to the presence of large numbers of other waterfowl here



Coastal lagoon in the Po Delta, Italy.
Photo courtesy of Paolo Volponi.

Sub-Alpine rivers are of particular interest for their Salmonid fish populations: the Soca River, Slovenia. Photo courtesy of Stef van Rijn.

and to the general complexity of this wetland system.

Different management programmes for the Cormorant-*vallicoltura* conflict are carried out by landowners in the two administrative regions of the Delta. This involves the use of non-lethal techniques, shooting, and partial financial reimbursement for damage. However the conflict is far from being solved and the multiple uses of the Po Delta wetland system make the management of the Cormorant conflict a complex task. Other than fishing and fish farming, wildfowl hunting may represent an ecologically and economically important resource for most fishing *valli*, providing large incomes often higher than those from aquaculture. Nature tourism is based on the great diversity of habitat and waterbirds in the area and represents a fast-growing economic resource, especially valuable outside the summer holiday season. The Cormorant conflict is thus one factor in a complex system of multiple uses for aquatic resources, fishing being only one of many objectives.

11.5 Slovenia (category: small rivers and pre-Alpine streams)

Cormorants exploit small running streams and rivers in Slovenia, mainly on migration and in winter during freezing conditions. As the lowland rivers and lakes become frozen over, the remaining Cormorants tend to concentrate on the faster-running streams where they forage in waters home to a variety of Salmonid species. Here, this region shares some key ecological perspectives (i.e. seasonal Cormorant predation coinciding with the main prey vulnerability period) to other places such as the Po Delta.

Although 'pristine' at first sight, the Slovenian environment has undergone some major changes (e.g. damaged/altered river courses by human activities, the construction of dams). These changes have had a negative effect on the occurrence of the typical anadromous fish species (i.e. those that spawn in freshwater but migrate to sea for most of their adult lives). However, from a biodiversity perspective, many threatened or endangered fish species still occur in this region (e.g. Atlantic Salmon, Marbled Trout *S. marmoratus*, Grayling *Thymallus thymallus*, Nase *Chondrostoma nasus*), sometimes actively managed by stocking programmes. These fish species and their populations deserve at least as much protection as do fish-eating birds and many have been protected under the EC-Habitat Directive.

Most Slovenian case studies do not demonstrate categorically a negative effect of Cormorant predation on either fish stocks or angling catches. However, Cormorants (first reported arriving in the winter of 1997/98) are claimed to affect angling catches of Grayling in the Soča River as demonstrated by fishing statistics of Fishing Club Tolmin. This observation could be alarming for two reasons. First, Grayling in the Soča belongs to a genetically unique Adriatic line (Susnik *et al*. 2001) and thus deserves particular attention. Second, it has been estimated that angling tourism contributes 2.3 million Euros to the local economy (Post *et al*. 2002). Likewise FC Novo Mesto has presented evidence of how Cormorants would affect angling catches even for a species like Nase, which is locally very abundant.

Twenty-two Cormorant conflicts cases were reported from Slovenia, on 19 rivers/sections of rivers and on three lakes. No conflicts were reported from the Fisheries Society covering the River Gradaščica. Most conflicts were reported from the middle reaches of rivers, at widths of 10–50 m and altitudes of 100–500 m. Most of these rivers are still natural and of low nutrient status.

Twenty-one fish species were recorded in conflict cases with Cormorants in the 19 Slovenian river case studies reported and a further two species were recorded in two lake cases. Slovenian studies on the diet of Cormorants have shown a wide variety of fish prey (see section 4.3), 88% of the wintering birds feeding on (commonly available) Cyprinid prey (Govedič 2001). As such, the situation described indicates the sensitivity of the system, at least as seen by the managers. Although most Cormorants prey on larger-scale water bodies (this is also where the main roosts occur at times of migration), smaller parts of the migrating population cause interference to fisheries interests in the high altitude streams. Although predation levels are difficult to quantify scientifically here, examples from similar river systems in Austria allow a more in-depth exploration of Cormorant impact in such systems.

11.6 Austria (category: small rivers)

Considering the interaction between Cormorants and fishes in small streams it is important to consider how possible impact might be measured. This potential predation pressure is key to explaining Cormorant conflicts in regions like Slovenia (see previously) and also in other regions such as Austria where angling for migratory Salmonids and Grayling is a highly valued sport. Cormorants visit smaller streams in the upper catchments of pre-Alpine rivers mainly in winter, mostly from roosts in trees along rivers further downstream. The ecological principle of saving energy by minimising travelling distances leads to the following hypothesis: that Cormorants will forage more intensely close to the roost than in more distant areas and thus predation pressure will decrease as a function of distance from the roost.

In order to examine this hypothesis, three Cormorant roosts in Austria were identified for further analysis according to their location and the local abundance of fishes. Radial distances of 10, 20 and 30 km around these roosts (representing potential Cormorant foraging distances) were drawn in ArcGIS

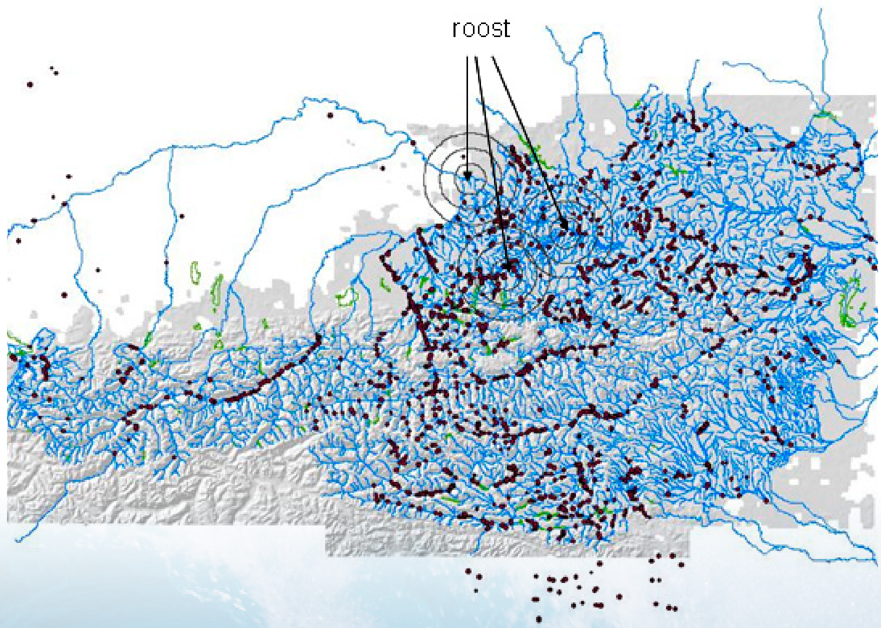


Figure 11.1 Determination of three potential Cormorant foraging distances around three roosts in selected areas of Austrian rivers where fish sampling data are available (dots indicate fish sampling sites). Graphic: R Haunschmid.

and all fish sampling sites and associated data were taken from the extensive Austrian fish data base (Figure 11.1). Sampling sites (n = 32 for Brown Trout and n = 23 for Grayling) in autumn were taken within each of the three possible foraging ranges around each individual Cormorant roost. Both abundance and biomass were determined for Brown Trout and Grayling at each fish sampling site, these species being of high fishery interest and the ecologically dominant ones in this region. For each sampling site the requirements for Moran-Zippin or DeLury estimations were fulfilled. In other words, sites were fished repeatedly and the resulting depletion in catches was used (statistically) to estimate the original number (and hence density) of fish at the site.

The mean value for numerical abundance and biomass (and 95% confidence limits around the mean) were subsequently calculated separately with a bootstrap analysis method for each of the three foraging distances from each roost. Overlapping confidence limits indicated no significant difference between sites.

The estimated fish abundances and biomasses at sampling sites located between 10 and 30 km from the roost sites differed significantly (Figure 11.2). The average abundance and biomass of both Brown Trout and Graying were about three times higher within the 20–30 km radius of roosts compared to those within 10 km of them (Figures 11.2 and 11.3). Brown Trout showed a continuous increase in both abundance and biomass with increasing distance from the Cormorant roosts but this pattern was not apparent for Grayling despite higher values at sites farthest from roosts

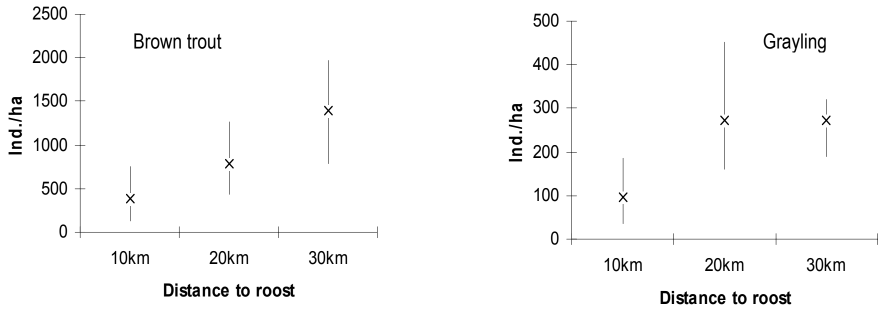


Figure 11.2 Estimated mean fish density (individuals/ha) for Brown Trout and Grayling at three different foraging distances from Cormorant roosts, bars represent 95% CL. Graphic: R Haunschmid.

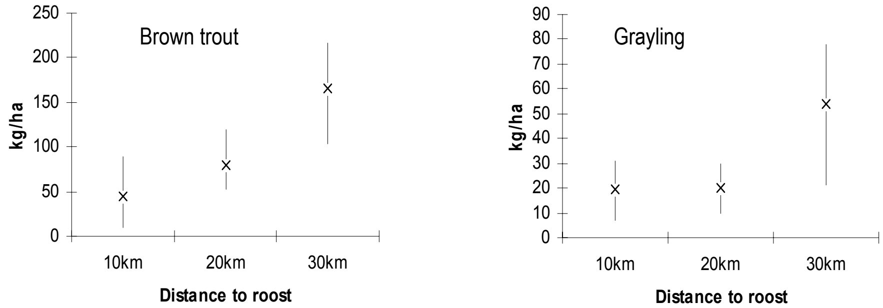


Figure 11.3 Estimated mean biomass (kg/ha) for Brown Trout and Grayling at three different foraging distances from Cormorant roosts, bars represent 95% CL. Graphic: R Haunschmid.

The significant difference in fish abundance and biomass in relation to distance from the Cormorant roosts could be caused by the foraging strategy of Cormorants in that they could be preferentially using feeding areas closest to their roosts in order to conserve energy. However, this apparently intuitive conclusion must be interpreted with caution because other factors could produce similar results, for example, the differing ecological status (hydromorphological condition) between the sampling sites or different human pressures on fish stocks. As Cormorant roosts are mainly situated in the lower altitudes of pre-Alpine rivers, the observed 'distance effect' in fish abundance and biomass coincides with a discontinuity in habitat between the areas where roosts are located and the more upstream areas where Cormorants forage. Furthermore, short-term abiotic events like flooding or site-specific differences in recruitment rates could affect the local performance of the fish populations. Thus, a good knowledge of the sampling sites and an adequate sampling design are required before correlations like the ones described here (rather than direct observations on the predators themselves) can be used to explain the patterns observed.

Indeed, one further observation from the available fish sampling data is in line with the alternative explanation outlined above that the differences in Trout and Grayling density and biomass are unrelated to increasing Cormorant predation with reduced distance from the roosts. When data for Chub (*Squalius cephalus*) are examined, using the same sampling methods and foraging radii from the three roosts, no significant differences in estimated fish density and biomass are found in relation to distance from the roosts. This is revealing because Chub is one of the more commonly taken prey for Cormorants in this region (Suter 1991, Schratter & Trauttmansdorff 1993, Govedič 2001), and so it might be expected that there would be a significantly reduced population of this species within the likely foraging distances of Cormorants from the roost sites. Thus, on current available information, there is very little (or no) evidence that Cormorants are depleting fish at the 'population' level around roosts in this region. Recorded changes in fish abundance and density are more likely the result of other biotic and abiotic site-specific factors than the result of Cormorant predation. Nevertheless, heavy localised predation pressure from Cormorants could affect fish abundance (of particular sizes and/or ages) in particular places (although rigorous data are still lacking on this). Thus an important ecological perspective here is that some fisheries may well be very vulnerable to Cormorant predation, not because Cormorants specialise on feeding at particular locations on particular species, but the reverse. As they are not restricted to feeding on Salmonids in pre-Alpine streams for instance, a highly mobile 'generalist' predator like the Cormorant could potentially impact on local prey populations, depleting stocks before moving out of the area to other feeding grounds.

11.7 South Bohemia, Czech Republic (category: medium sized rivers, fishpond areas)

Important factors in the Czech Republic that are thought to influence the relationship and the conflict between Cormorants and fisheries here are the trends in (i) Cormorant numbers (which are increasing) and (ii) the general economic situation (which is declining nationally). Here, Cormorant problems are closely associated with the pond farming industry, primarily for Carp (*Cyprinus carpio*). There is no general problem with Cormorants on reservoirs where there is little fish stocking and so no significant economic loss to Cormorant predation. There are some Cormorant problems downstream from reservoirs in secondary trout fisheries. Here, river sections (and very occasionally reservoirs) are stocked for angling. Although anglers say there is a Cormorant problem on rivers, the perception of damage caused by these birds held by different stakeholder groups appears to depend on local conditions, and a nationwide overview of the situation is currently lacking.

Cormorants and Otters: a comparison

For a better ecological understanding of the fish consumption by Cormorants in the Czech Republic, estimates of this were compared with those for another fish-eating predator that occurs in the area. South Bohemia is renowned for its Otter (*Lutra lutra*) populations that are thought to be relatively large and are covered by considerable conservation legislation. The area thus includes two top predators in aquatic systems, one 'globally', considered scarce and the other considered abundant but both being high-profile species within local water systems. The ecological perspective explored here involved calculating rough estimates of the amount of fish eaten by both Cormorants and Otters.

Carp harvest in the Hranicny fish pond area, Czech Republic.
Photo courtesy of Petr Musil.

Otters are a highly protected species throughout the country and numbers have increased. The species is widely distributed

and has expanded in South Bohemia. Otters are an important and widely esteemed part of the mammalian fauna. Widely available data on fish consumption from local experts and from the available literature was used to derive adequate fish consumption estimates for Otters.

Roughly 8,000 Cormorants winter in Czech river areas (from November till February), about 1,500 migrate (in October and March), whilst there are no breeding birds. In pond areas about 500 birds wintering, about 9,000 migrate, and 1,000 birds breed. In reservoirs roughly 1,500 birds winter, about 7,000 migrate, and no birds breed. Table 11.1 shows the presence of Cormorants (expressed in 'bird days') based on the actual numbers of birds counted and the length of time that they are resident on specific types of water body during winter, summer (breeding) and migration periods.

Assuming that (*sinensis*) Cormorants take around 400 g of fish each day, indicates that roughly 940 tonnes of fish are eaten annually by Cormorants in the Czech Republic. Otters eat approximately 1 kg of fish per day and 1.3 kg when they have offspring (during 4 months of the year). The Czech Republic holds about 2,250 Otters and it can be calculated that this population consumes roughly 891 tonnes of fish each year (Table 11.2). When comparing these 'global' consumption rates (i.e. 940 t by Cormorants, 891 t by Otters), the conclusion is that both predators consume freshwater fish at an overall level that is certainly of the same order of magnitude. The interesting thing here is that all discussion about economic losses at freshwater fisheries centres on Cormorants whilst Otters (at least) consume similar amounts of fish, often in the same habitats, as do Cormorants.

11.8 Saxony, Germany (category: complex of artificial lakes and reservoirs, small lowland rivers and fish pond areas)

The area, a Biosphere Reserve, is a complex system comprising medium-sized rivers, artificial lakes and many small ponds (Table 11.3).

In this area, the average number of 1,000 'resident' Cormorants rises to about 4,000 birds in August and September, before declining sharply thereafter. Few birds are present from March to June, and these birds are mainly on migration or non-breeders staying in the region over summer (Figure 11.4).

Conflicts between Cormorants and fisheries occur mainly in the fishpond areas in this part of Saxony. Financial compensation for estimated fish losses to Cormorant predation is paid and fishing

Table 11.1 Presence of Cormorants (bird days) in the Czech Republic for three major water system types during three different periods of the year.

Bird days (x 1,000)	Winter	Summer	Migration	Total
Rivers	960	-	90	1,050
Ponds	60	160	540	760
Reservoirs	120	-	420	540
Total	**1,140**	**160**	**1,050**	**2,350**

Table 11.2 Rough estimates of the total annual fish consumption by Otters (*Lutra lutra*) in the Czech Republic.

Number of Otters (2,250)	Presence (in months)	Daily consumption (kg)	Total consumption (tonnes)
Solitary	8	1	540
With young	4	1.3	351
Total			**891**

companies can get permission to remove nests and eggs by flushing them out with high-pressure water sprays. Cormorants also feed in a nearby reservoir and so there are no conflicts with surrounding fish farmers at some ponds as the birds have alternative foraging sites.

In a similar situation to South Bohemia, there is also a relatively strong Otter population in the area (perhaps about 300–400 individuals), and they are also considered an important element of the regional fauna. There is also the possibility here of obtaining financial compensation if Otters are known to cause damage to fisheries.

Predation by Cormorants was estimated roughly in order to give a general, broad-brush context to the biological picture in this case study area. Starting with an assumed average fish consumption rate of 400 g per (*sinensis*) Cormorant per day, and multiplying this by the number of Cormorant days per month, produced as estimate of annual fish consumption. The total amount of fish in the area was again very broadly estimated for three groups of water bodies, (1) carp ponds, (2) reservoirs, and (3) 'non-managed' water bodies, including recently formed lakes in former coal mine areas. This calculation suggests a range (based on maximum and minimum bird numbers, variations in dietary assessments, and amount of 'available' ice-free foraging habitat in winter) of some 100–170 tonnes of fish consumed per year by Cormorants. Of this, around 50–130 tonnes is likely to be Carp.

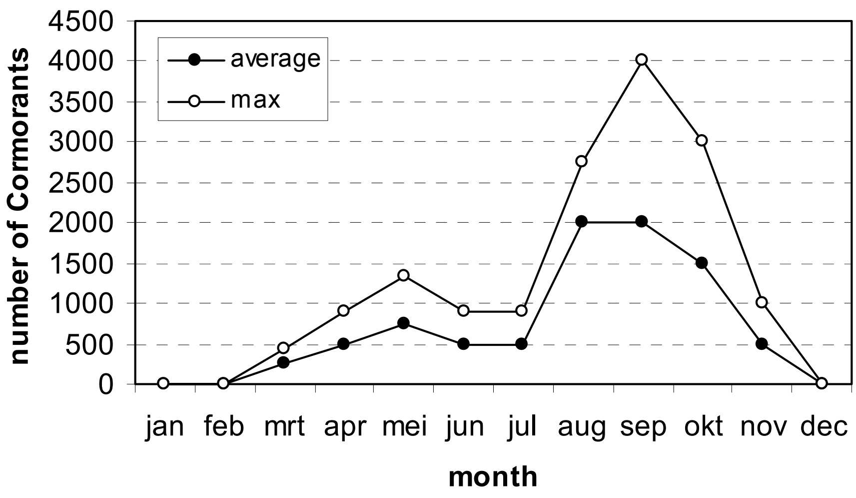


Figure 11.4 Monthly changes in Cormorant numbers present in the Saxony Biosphere Reserve study area.

Figure 11.5 shows the estimated production of fish and associated predation by fish-eating birds including Cormorants in the region of the Biosphere Reserve. Carp are mainly found in the fishpond area, whilst other fish species are more abundant in other waters but do also occur in Carp ponds according to local experts.

Table 11.3 Surface area of waterbodies according to water habitat type in the Saxony study area.

Water body type	Surface (ha)
Special protected area (SPA reservoir)	700
Open cast mining (new reservoirs)	2,000
Fish ponds (privately owned)	2,114
Others (small water bodies)	1,300
Total	**6,114**

As well as Otters, other fish predators in the area include a variety of birds and mammals, which are all inhabitants of the Biosphere Reserve. Some 150 White-tailed Eagles (*Haliaetus albicilla*, 15 nests), 400 Otters, and numerous Grebes, Herons, Egrets and Gulls all forage in the area. Thus a key ecological perspective here could be explored by comparing rough estimates of the total fish consumption by all these species with that estimated for the Cormorant (Figure 11.6). These calculations allow the amount of fish lost to Cormorants to be compared with that taken by other members of the fish-eating predator community in the region. They suggest that Cormorants might consume roughly half of the overall estimated fish predation by wild animals in the area. Although crude, these calculations suggest that it is important to take these losses to other predators into account when considering the Cormorant problem, in order to put the latter into context.

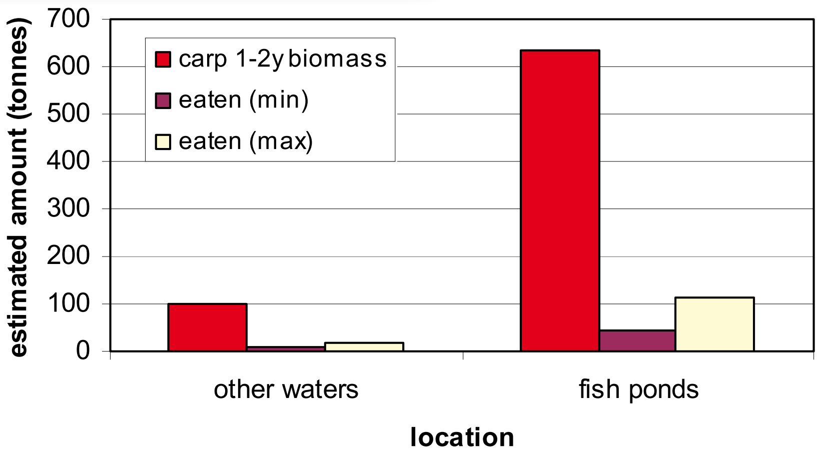
Another important ecological perspective here is that landscape

Typical Carp pond during fish harvest, near Bautzen in Lower Saxony, Germany.
Photo courtesy of Stef van Rijn.

change their location according to local preferences or changes in food supply. Another ecological observation from the area is that the presence of large-scale, open water bodies in the form of impounded stretches of river, reservoirs and the new lakes in former coal mine areas, add significantly to the picture of extensive inland wetland habitat. The fishponds are thus surrounded by additional water bodies, which undoubtedly attract avian (and other) fish predators.

It is thus likely that any human-induced disturbance in the pond characteristics are very likely to affect predation levels in this area with a highly patchy distribution of water bodies. The 'availability' of these water bodies to Cormorants will be related to (1) the geographic location, (2) the position of roost sites, and (3) the accessibility of the waters to foraging birds (i.e through such factors as water transparency, level of disturbance, fish size and density, distance to nearest roost).

Figure 11.7 shows that Cormorant roosts in the area occur at regular distances from each other, well-spaced out across the entire area. The average distance between night roosts is 9–12 km, apparently the ecologically optimal distance for Cormorants to exploit the area. Another important ecological perspective here is that the entire fishpond system is thus easily within reach from this set of roosts and Cormorants can



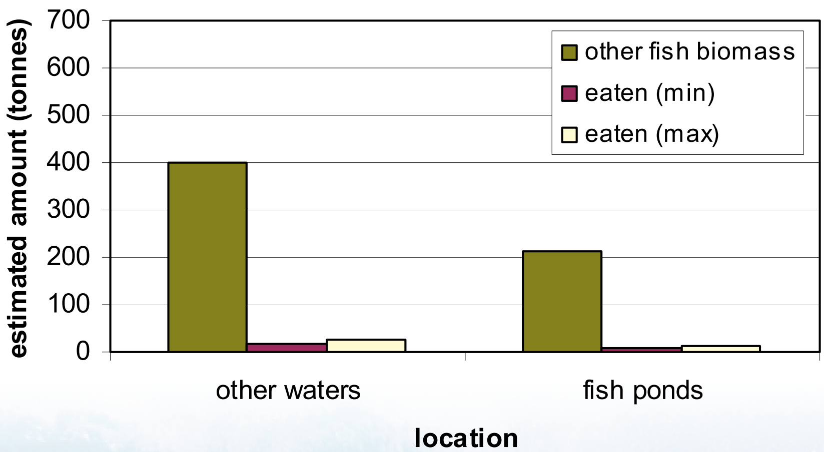


Figure 11.5 Estimated abundance (tonnes) of Carp and other fish species in the Saxony fishpond area and 'other' water bodies, together with the estimated amount of fish consumed annually by Cormorants and other predators. Predation levels are presented as minimum and maximum estimates. Year 1–2 Carp are specified as they constitute the most common size taken by Cormorants.

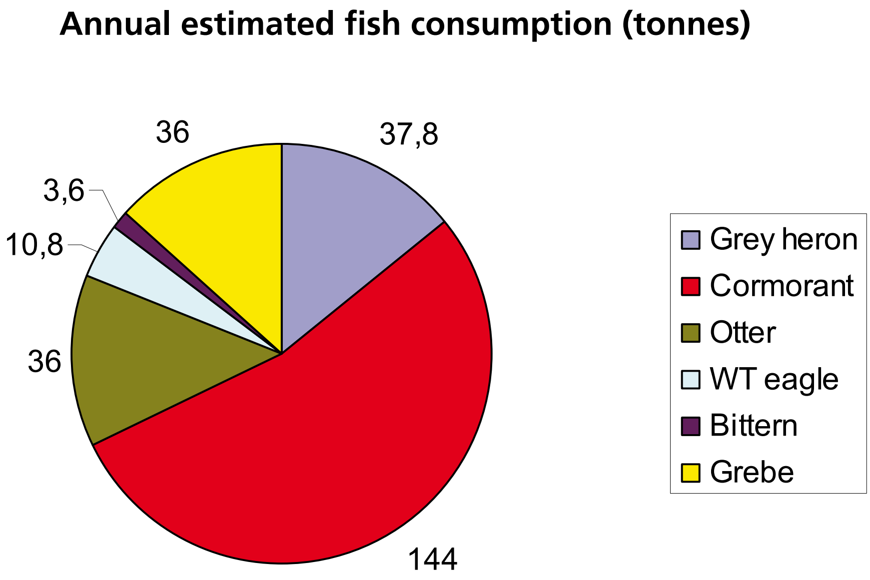


Figure 11.6 Estimated amount of fish consumed annually by fish predators in the Biosphere Reserve Area, Saxony, Germany.

area (in an attempt to reduce Cormorant numbers at ponds) can easily be overcome by the birds because of the large amount of 'refuge' habitat available nearby. The increased availability of feeding and roosting sites caused by restoring the landscape from former mining activities is also very likely to have contributed to the increased levels of predation pressure on individual ponds.

11.9 Hula Valley and Bet Shean Valley, Israel (category: fishfarms)

Cormorants from Eastern Europe (records of ringed birds from the Ukraine) winter in Israel but birds also pass through the country to areas further south. Thus one ecological perspective here is the migration and over-wintering pattern of the birds. Israel has lost the majority of its freshwater wetlands and many of them have been diverted into arable land or fish farms, although some patches have recently been restored in the Hula Valley. Thus, an important ecological perspective here is the general shortage of water systems. For economic reasons, some ponds in the Hula Valley area have been converted to orchards in the last few years, and during **INTERCAFE's** visit to the Hula Valley there was discussion of the possibility that all the farms there will cease fish production within the next couple of years. As well as predation issues with Cormorants, wires and cables mounted above the ponds have been used to prevent White Pelicans (*Pelecanus onocrotalus*) from landing on fishponds.

Water in this region is too cold in winter (around 11°C) to grow Tilapia which are valued much more so than Carp. With Cormorant predation on top of this, these are real concerns over the viability of such farms. Farms here are radically different to those in the Bet Shean Valley further south along the Jordan River. Here, the water temperature is higher, which facilitates the growing of a wider variety of fish.

Cormorants roost in the Hula Nature Reserve most of the day but leave to feed in the adjacent

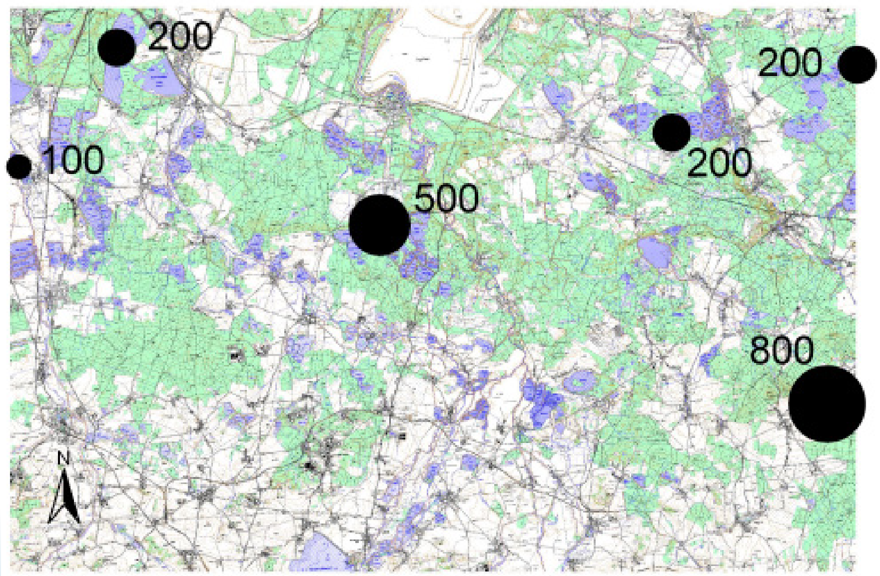


Figure 11.7 Biosphere Reserve and adjacent territories in Saxony, Germany (Biosphären Reservat Oberlausitzer Heide und Teichlandschaft), showing fish ponds, natural water bodies and recently flooded lakes in former coal mine areas. Roost location and maximum estimated roost size (number of birds) are indicated by black circles. Some roosts are situated just outside the borders of the Reserve.

The large and turbid waters of Lake Kinneret, Israel, attract large numbers of wintering Cormorants.
Photo courtesy of Stef van Rijn.

reservoir. However, they have caused few problems here in the last few years because numbers are now much lower than previously. It is interesting to note that this seems to be a more common theme — a Nature Reserve adjacent to a commercial fishery. Management of both areas is not considered in isolation but in an integrated manner; the predators need a safe place to shelter but can be disturbed at vulnerable sites.

Scientific knowledge about feeding conditions and the foraging behaviour and skills of the predators plays an important role in the way Cormorant problems are managed here. Similarly underwater visibility is an important issue in the acuity of the Cormorant to detect, pursue and catch its prey (Strod *et al*. 2004) so physiological issues are also important. Fish in their turn depend on basic habitat characteristics like shelter, food and oxygen supply. These factors differ across water bodies and determine the position of predator and prey. Specific research was conducted to unravel these factors and implement the system-based knowledge through local management.

The reservoir Agmon can suffer severe oxygen depletion and, under these conditions, fish move up to the surface and Cormorants concentrate their feeding in the top layer of water. Moreover, the Sea of Galilee (Lake Kinneret) is a natural feeding place for the birds. Part of the solution to the problem of reducing the impact of Cormorants at farm ponds is supposedly to increase the use of this water body by wild birds, thus offering a good alternative to foraging at the fish farms. Thus, influencing the birds' foraging site-choice is yet another ecological element of local management. The Sea of Galilee is fished by commercial fishermen but (perhaps also due to its huge size) Cormorants and fishermen do not appear to be in conflict here.

In Bet Shean the situation is economically much more powerful than it is in the Hula Valley, and the methods to deter Cormorants are considerably more intensive. Gas cannons, fireworks and direct shooting are applied on a large scale. Fish stocks are huge (over 10,000 kg/ha) and this means that Cormorant predation (or visits from any predators) are seen as an unacceptable stress factor, given the extremely high fish densities. The situation in Bet Shean was at the extreme end of the range of possible anti-predator measures seen across

Europe and was presumably associated with the extraordinary high investments and economic values of the fish farms there.

The Israeli case of integrated management of water bodies for different purposes was not confined to Cormorants. For White Pelicans too, the management solution bears parallels with that of the Cormorant as this species can also be a nuisance to the fishfarmers at times of migration. As preservation of the White Pelican constitutes a stronger conservation goal than does Cormorant conservation, an integrated solution was first developed for this former species. This was based on providing the flyway population with abundant food and undisturbed stopover sites in a natural environment in combination with maintaining the 'traditional' fishfarm practices (Shmueli *et al*. 2000). Surplus food from fish farms was put in the Agmon reserve and was thus used to concentrate the Pelicans in the nature area. A similar strategy, this time with agricultural crops, was also developed for Cranes (*Grus grus*, Gutman *et al*. 2001).

12 DISCUSSION

This chapter explores two aspects of Cormorant-fisheries interactions in more detail: (1) the data on numbers and distribution and (2) Cormorant ecology. We aim to put the data into the perspective of reliability, data completeness and ecological context.

12.1 The number of Cormorants

12.1.1 What is 'Europe' and which populations are we talking about?

Cormorants, like many other birds, show large differences between summer (breeding) and wintering areas. Compared to the breeding distribution, the wintering one covers a much larger geographical range and birds are far more widely dispersed. In summer, the majority of breeding colonies are found in coastal areas, whilst in winter inland lakes and rivers are also important habitats. Comparing the general patterns of distribution in summer and winter shows striking differences (Table 12.1) between 'populations' of Cormorants in three geographic regional areas (A, B, C, see also Figure 6.1). Thus, 'Europe' can be a fuzzy concept when considering Cormorant populations. In fact there are several populations existing at the same time and in different places across a very large land surface area. Only birds in regional groups A and B correspond to the EU-27 region (but often migrate out of it in winter). The birds of group C are largely confined to non-EU countries throughout the year. They also move further south in winter and this part of the population is far less studied, both in terms of number and in terms of migratory habits.

In winter, the Atlantic-North Sea region (A) has about half of all estimated birds, whereas in summer the largest proportion breeds in the Baltic-Central European region (B). This is a result of the fact that some of the Baltic birds migrate west to winter in the area included in the Atlantic North Sea region. It is important to emphasise that it is thus vitally important to define precisely the geographical area under consideration when talking about Cormorant numbers 'in Europe', whatever area that might be. It is also important to recognise that, at this level of geographic scale, Cormorants are distributed in significant numbers over a very wide area. Although overlap occurs between the major regional groups, the majority of birds do not roam about freely in the 'super space' of Europe, nor within any of the three regional areas. Distinct (sub)-populations occur, often with discrete migration patterns. To date, knowledge about these migration patterns has been described only partially.

Many Cormorants from eastern Europe winter in the Middle East as here at Lake Kinneret, Israel. Photo courtesy of Stef van Rijn.

Coordinated ring analyses could be used to expand our knowledge with respect to the geographical segregation of regional groups and to refine our understanding how individual movement and migration strategies have developed. Such knowledge and understanding is necessary in order to understand the birds, especially when comparing count data when analysing trends, or when the link is made between numerical distribution and perceived damage. Merely mentioning the overall numbers of cormorants, suggesting that these would be one huge pool of birds that could potentially show up at any one site, is very far from the actual situation described here for the European continent.

12.1.2 How comparable are the population data?

The number of Cormorants assessed independently both in winter and summer corresponds reasonably well, especially for regional groups (A) and (B), that is for western and central Europe together. Given the more recent count of breeding Cormorants, the 755,000 *sinensis* estimated for January 2007 (based on the breeding count in 2006) would correspond to an estimated 558,000–615,000 birds in January 2003. This range depends on the assumed number of non-breeders and the estimated total should be compared with the actual number of birds counted, which was almost 427,000 *sinensis* Cormorants in this region in January 2003. Given the different methods and completely different geographic areas used by the birds in summer and winter (see Figs 6.2. and 6.3), both estimates compare reasonably well. Because the winter count includes 'uncounted' areas in Eastern Europe and/or some birds may have completely left the region being counted (i.e. other Middle Eastern countries, Sudan), the estimate based on the summer count is higher. Another alternative possibility is that the actual survival and/or the overall number of non-breeders is less than was assumed, thus leading to an overestimate of the most recent count.

The proportional occurrence of the Cormorants between summer and winter differs between the different regional groups in Europe (Table 12.1). The Atlantic-North Sea area (A) is relatively more important in winter, being estimated to hold 51% of the estimated wintering population there. In contrast, in summer, the Baltic regional area (B) is estimated to hold the largest proportion 44% of breeding birds.

Great White Pelicans (*Pelecanus onocrotalus*) and Cormorants fishing together in the Danube Delta, Romania. Photo courtesy of Botond Kiss.

Table 12.1 Comparison of counts of Cormorants in 47 countries in the Western Palearctic, including North Africa and the Middle East, in winter 2003 (birds) and summer 2006 (occupied nests), separated into three geographic regional groups.

Regional Group 'metapopulation'	January 2003		Summer 2006	
	Number of birds	(%)	Number of nests	(%)
(A) Atlantic-North Sea	346,524	(51)	121,763	(33)
(B) Baltic-Central Europe	214,413	(32)	162,691	(44)
(C) Black Sea-East Mediterranean	114,898	(17)	87,882	(24)
Total	**675,835**		**372,336**	**100%**

12.1.3 How many Cormorants do we have in total?

To answer this question in a meaningful way it must be refined to a specific geographic area. The regional division into three groups suggested here (see Figure 6.1) is a first attempt at this. An analysis of the migratory movements of ringed birds could be used to elaborate, and to distinguish in a more sophisticated way, between different Cormorant sub-populations. From the overall

number of breeding pairs in regional areas (A), (B) and (C) (*carbo* and *sinensis* combined), the total number estimated is 372,300 breeding pairs. Applying the same conversion factor as derived for the *sinensis* population in areas (A) and (B) (i.e. 3.25), and 'converting' from breeding pairs in summer to January numbers in the winter after, it could be tentatively estimated that there were 1.2 million birds throughout the whole Western Palaearctic region in January 2007. It is important to note that this geographical area is considerably larger than the EU-27 region. The Western Palaearctic stretches from Iceland, Portugal and Morocco in the west to the Caspian Sea, Turkey and Iraq in the east, and from Greenland and the Barents Sea in the north to Algeria, Egypt and Saudi Arabia in the south.

This January 2007 estimate is lower than the post-fledge annual maximum number of birds that would have occured in July 2006, just after most young have fledged, as birds will have been dying continually from fledge in late summer throughout the autumn and winter up to January. On the other hand, this estimate is higher than that just prior to the new breeding season, as mortality has continued over the entire winter period and during the spring migration. However, any interpretation of this figure must be treated with caution as not all these birds can be strictly classified as 'European', as this 'population' is distributed over a very large area, including parts of the Middle East and northern Africa.

Nevertheless, this estimated January number derived from the breeding data can be seen as a reasonable approximation of the number of birds at that time of year. By calculating backwards from counts of breeding pairs, an estimate for the production of young over the entire geographic range was needed. By applying *sinensis* data for the entire population (including the less productive *carbo* portion), will certainly lead to an overestimation of numbers. Similarly, the assumption of a cohort of 100,000 non-breeding birds is also not too conservative in this respect. Finally, the mortality rates of young-of-the-year birds may be higher than assumed here. The population data used are derived from the protected western parts of the species' range, and mortality in the eastern parts is likely to be higher than this — but relevant data were not available to allow this assumption of equal mortality over the wide geographical range to be refined spatially. There are thus several reasons why this overall population estimate, although based on best available scientific information, should be considered with caution. However, as pointed out above, it is certainly not to be considered an under-estimation of the actual number.

12.1.4 Counting effort and numerical assessment during summer and winter

To date, two Pan-European Cormorant counts have been conducted, one in summer the other in winter, and the spatial information provided by them gives a reliable picture of distribution across large parts of Europe. As birds are far more dispersed in winter than in summer, overall trends in the overall population size are probably best censused by counts at breeding colonies.

Nevertheless, winter counts are useful to detect trends in regional areas and to provide important additional information about large-scale trends in regional distribution. The amount of counting effort required in winter is far beyond that needed to count the colonies in summer. This is related to the larger geographical range to be covered in winter as well as the fact that there are at least five times more winter roosts than there are breeding colonies in summer. Also, the severity of prevailing weather conditions across Europe during a mid-January roost count should not be underestimated. Complete winter roost counts are very difficult to achieve, especially in areas like the Maghreb countries, Libya, Egypt and Sudan. In fact this holds for a much wider geographical range, as in southeast Europe, Turkey and Lebanon especially, current data are incomplete and do not show the numerical distribution at the most detailed geographical level. However, because the temperature gradient across Europe excludes a lot of potential winter habitat, the situation described here will largely depict the real pattern of Cormorant occurrence in Europe in winter.

Although breeding colonies are situated over a smaller geographic area than are winter roosts, it is likely that some breeding attempts were missed, at least in some countries. Despite best efforts to compile a complete list of colonies for each country, either the existence of some colonies was not reported or important details were not available. Despite their large and often conspicuous nests, counts of Apparently Occupied Nests (AON, the standard method of counting breeding Cormorants, see chapter 2 [especially section 2.2] of Carss *et al.* 2012 for full details) were not always straightforward. For example, some countries were faced with the difficulty in surveying coastal colonies, on cliffs, stacks or offshore islands and, in many cases, not viewable from land and so for some of these colonies, boat-based or aerial surveys were conducted. After the end of the breeding season, the coordinators collated data from the counters (in most cases on a national scale) and then reported to the central organising group who checked for mistakes and converted information into databases containing data from all countries.

The coverage of breeding counts was considered satisfactory, although it took many months to gather data from all relevant countries. By the end of the work, the EU-27 region, Norway and Switzerland were very well covered. However, the WI-CRG was unsuccessful in obtaining reliable information about the occurrence of breeding Cormorants in Bosnia and Herzegovina, Albania, Macedonia and Moldova. It was also difficult to obtain complete coverage of breeding colonies located in countries east of the EU-27 region, but also for *carbo* birds on the remote Atlantic coasts. However, there was some success in 2008 in obtaining information from countries like Ukraine, large parts of European Russia and Turkey. Population estimates for these countries can still be improved but the survey was considered successful in that it showed for the first time the number of breeding pairs in a very large geographical range. Again, it is important to consider the breeding counts in their geographical context. The birds show strict migratory patterns, which implies that only a proportion of the total number will ever migrate to any particular region. This means that it is almost certainly invalid to consider the biological relevance and/or the economic impact of Cormorants on fisheries in particular regions, countries, or within the EU-27, purely on the total number of so-called 'European' Cormorants.

The census work of WI-CRG stimulated count initiatives on a national level in many places. Furthermore a number of countries have now reported the national results of the Cormorant colony count in 2006 in reports, scientific papers, official reports, popular journals (including newspapers) and/or on the internet (e.g. Eskildsen 2006, Staav 2007, Herrmann 2007, Kirikova *et al.* 2007, Newson *et al.* 2007, Shurulinkov *et al.* 2007, SYKE 2006, van Rijn & van Eerden 2007). A number of results from the 2006 count of breeding colonies have been published in scientific journals. A wrap-up from the counts has also been presented at a European parliamentary level in the 'Cormorants in the Western Palaearctic: Distribution and numbers on a wider European scale' (WI-CRG, October 2008).

It is interesting to compare the amount of effort that was needed to perform these counts. In summer the 2006 breeding count was done by approximately 100 people, whereas at least 2,500 individuals were involved in the 2003 winter count. From the point of view of human-effort, a breeding census is therefore easier to conduct than is a full-coverage winter count.

12.1.5 What future census work is needed?

Based on the available data from two integrated Cormorant counts across Europe, a fairly clear picture of Cormorant status and distribution across the continent can be drawn. However, as the populations are subject to change due to weather conditions, shifting food supplies, management measures and other factors, repeated censuses are necessary, both in winter and in summer. From this (and earlier work), count data point towards declining Cormorant numbers in the southernmost wintering areas which may be due to milder winters in central and Western Europe. Nevertheless, special effort is required to have areas counted comprehensively in northern Africa, the Middle East and Turkey. On the other hand, the still expanding breeding population in the Baltic needs further study in relation to numbers and migratory pattern. The detailed distribution and migratory patterns of birds breeding in the eastern Baltics, Belarus, northern Ukraine, parts of the Russian Federation and Georgia are little, if at all, understood and require attention. For instance, the finding in Israel of birds ringed in Ukraine is actually no proof that other countries in that super-region (e.g. Belarus and Russia) are not also the 'home' countries to breeding birds during summer that also spend the winter in Israel. The ringing efforts in these countries is simply too low to draw such a conclusion. Finally, the reproduction and dispersion of *carbo* birds needs further clarification for large parts of the range. For example, the degree to which carbo birds intersperse in the continental winter range of *sinensis* is still largely unknown.

Another important point requiring clarification is the count of summer roosts and of non-breeders within colonies during the time of breeding counts. Total population estimates are best based on complete coverage during the same year. The non-breeding summer gatherings consist of immature birds but also of adults that are not breeding. Some of these birds are also present in the breeding colonies and so information about overall numbers needs to include these birds (which are not covered through standard counts of Apparently Occupied Nests). Current (and future) data on overall population structure, reproductive and mortality rates and on the temporal (and spatial) trends in these parameters must be followed-up by extensive modelling in order to predict future population developments. Modelling efforts so far have already pointed out the plasticity of the European Cormorant population with respect to counteracting the local effects of poor breeding performance. The recurring conclusion has been that only through enormous management effort could Cormorant numbers ever be brought back to the level of, say, 1985. The carrying capacity of the foraging waters for Cormorants in large parts of Europe is such that the population will 'easily' restore itself to the ecologically adjustable level, that is related to the availability of large quantities of of immature fish and smaller species which predominate in many ecosystems at present (see 12.2).

The Black Sea population of Cormorants has been relatively little studied so far, Danube Delta, Romania. Photo courtesy of Botond Kiss.

12.2 Cormorant ecology

12.2.1 Distribution and environmental factors

From the description and analysis of factors which determine Cormorant numbers and ultimate geographic distribution, climatic factors appear to be crucial. Wintering Cormorant distribution is shown to correlate well with an average January temperature of -5°C. This is the boundary temperature below which the average, larger standing waters freeze and also that at which slow-flowing larger rivers partly freeze, especially in shallow areas. Cormorants are distributed in an irregular manner in areas with mountainous landscapes. Here, regularly occupied roosts persist in the valleys of larger rivers from which Cormorants exploit the still unfrozen waters nearby. During periods of severe frost, birds are forced to move to ice-free regions but they also explore fast-flowing upstream areas. In these areas, the distribution of Cormorants thus changes rapidly according to the weather conditions. In the North, the deeper coastal areas also remain largely unfrozen at this temperature. Again, comparable to large rivers, the shallow sections do sometimes freeze and birds are forced to forage in deeper waters. At the European level, this temperature threshold well describes the general pattern of Cormorant distribution. Interestingly, within the range of temperatures higher than -5°C, there is a gradient in Cormorant distribution from the colder to the warmer areas (e.g. increasing density from northern and western Germany to France and Spain). Besides the actual freezing of waters, (which is the proximate factor affecting fish availability if waters are frozen, Cormorants can not feed there), temperature also has behavioural and energetic effects. For instance, it is likely that a species-specific relationship exists between the temperature at which fish are still active and at which they start forming winter aggregations in deeper water. Similarly, falling winter temperatures are likely to reduce the swimming speed of fish (perhaps making them easier for Cormorants to capture) whilst maintaining body temperature during foraging in cold water will require more energy (ultimately being derived from food intake) — such interrelated issues could also ultimately contribute to the winter distribution of Cormorants.

Zahori fish pond in the Czech Republic in winter. Most shallow and standing waters in eastern Europe freeze in winter and Cormorants move further south and/or to running waters. Photo courtesy of Petr Musil.

In summer, Cormorant breeding colonies also appear to be distributed according to temperature. A clear temperature-dependent start to the breeding season was found, to a large extent explaining the observed difference of more than five months in the start of breeding

across Europe. Interestingly, this earlier start of breeding in western and southern Europe appears limited in relation to the average maximum temperature later in the breeding season at the time when the young fledge, as few colonies occur in the area where temperatures reach more than 25°C at the time of fledging. The colonies in this higher summer temperature zone are in the interior parts of Spain, Italy, along the middle and lower Danube and the northern edge of the Black Sea. That this summer temperature level is probably ecologically the highest the birds can cope with, is corroborated if considered alongside data on post-fledge movements. Almost all fledged birds quickly move out of the breeding area where average maximum temperature exceeds 24°C and many move out of breeding areas where it exceeds 22°C. The post-fledge staging sites around the North Sea and Baltic Sea are situated in the core area of this temperature range (19°C to 22°C), both in relation to the start of breeding (North Sea, March) and post-fledge conditions (Baltic, July). According to the analysis, this may seem less true for the Black Sea and Azov Sea, as well as for the greater part of the Mediterranean. However, due to the fact that ambient air temperatures were used in the present analysis, areas close to large water bodies could in fact provide a microclimate that is actually cooler than presumed (at least water temperatures are likely be more buffered against temperature extremes and wind effects near large water bodies provide extra cooling).

There is still no explanation for why Cormorants in the Mediterranean do not breed in larger numbers than they do in January, as it is still not too hot in April. This is unexpected because breeding in January, or even December, has been recorded in several cases in the Netherlands, although the average start of breeding here is in March. Fish availability in January at these Mediterranean sites could be a limiting factor and/or that the necessity of migrating considerable distances north after the breeding season does not fit the annual cycle of movements. On the contrary, Cormorants with a late start of breeding incur only a moderate temperature increase after breeding. Those breeding in January generally face a sharp increase in temperature which often forces them to move to other areas later in the season. Interestingly, the birds could theoretically breed twice in a season if they migrated north.

The conclusion from this 'temperature window' hypothesis is that Cormorants are susceptible to climatic conditions. As milder winters occur due to global warming, there is an increasing possibility for this species to winter and breed at more northerly latitudes. As the total available water surface area is also likely to increase with climate change, this might well mean a further increase in Cormorant populations in Europe.

12.2.2 Food and feeding ecology

The Cormorant is an opportunistic forager and, for the greater part of the population across Europe, depends on large-scale open water bodies. Whether fresh, brackish or salt water, suitability as a foraging site is apparently dictated by the presence of relatively easily-caught and abundant fish. For almost 180 site-specific cases across Europe, the Water Systems Database developed during **INTERCAFE** provided useful information about feeding conditions and the Cormorant's response to it. The sampled area during this project comprised about 30,000 km^2 and was estimated to be used by a total of around 350,000 Cormorants. The analysis of these data from widely distributed sites confirmed the broad-scale pattern that emerged during the case studies where regional conditions were examined in greater detail through exchange of information with local experts

Cormorant feeding its young. Overall in Europe Cyprinid ('Carp family') fish species constitute the most common food items taken.
Photo courtesy of Florian Möllers.

and stakeholder groups. However, the Database comprises far more water systems than could be visited and is thus of considerable generic value.

It could be argued that the method of reviewing existing information on different water systems could be highly biased because of a lack of certain information or an over-representation of particular water body types. To some extent this is the case. For example in Table 9.1, 69 cases out of 179 (38%) relate to fishponds and small reservoirs, sandpits and smaller running waters. This is of course proportionally much more than the water surface-related occurrence of these habitat types in the field.

This is perhaps not surprising, the foundation of the Water Systems Database was invariably a specific location (or 'case') where there was perceived to be some form of conflict or interaction between Cormorants and fisheries interests. It therefore follows that the prey species highlighted most frequently in these cases are often those associated with both the habitat types most likely to be used by fisheries interests and those species that these fisheries catch or rear.

Thus, generally, the data held within the Water Systems Database provides information on particular fisheries habitats and has a clear focus on the position of commercially important fish species. This holds for Eel (*Anguilla anguilla*) in almost all waters, Pikeperch (*Sander lucioperca*) in large lakes, Grayling (*Thymallus thymallus*), Atlantic Salmon (*Salmo salar*), Brown Trout (*S. trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) in running waters, all species for which the importance in the diet of the Cormorant is often over-emphasised to a variable degree in reports from these water systems. Compared to the published lists of fish species derived from pellet analysis, Cormorant diet is generally more diverse, reflecting the diversity of fish species in various water bodies, with a less prominent role for these relatively 'rare' species highlighted by a focus on Cormorant-fishery conflict cases/sites. For instance, from extensive studies of Cormorant pellets from birds foraging in running waters in Slovenia, between 25 and 30 fish species have been recorded as prey. The conclusion from these and other more in-depth studies was that Cormorants rely on relatively small, abundant (and thus relatively easily caught) fish, rather than deliberately selecting the economically important (and often numerically less abundant) species of high commercial/recreational interest. As such, this situation is fully comparable to those extensive studies carried out in many large rivers, lakes, estuaries and coastal systems throughout Europe.

In general, Cyprinid fish species constitute the most important prey group of *sinensis* Cormorants in Europe. Of these, Roach (*Rutilus rutilus*) is undoubtedly the most commonly taken species (more than 50% of overall biomass consumed on an annual basis). The Percids Perch (*Perca fluviatilis*), Ruffe (*Gymnocephalus cernuus*) together with the Cyprinids Carp (*Cyprinus carpio*) and Bream (*Abramis brama*) roughly form another 30% of the estimated overall food intake by Cormorants. The remaining 20% of the diet comprises more than 100 fish species, proportions of which are site-specific and dependent on water systems and time of year. Although for individual water systems such species may comprise an important food resource, for the Cormorant as a species they have little importance and the birds by no means depend on them. This conclusion that Cormorants depend on only a few fish species has important implications with respect to the issue of the birds' interference with man's fishery interests, which will be discussed further in chapter 13.

12.2.3 Stocking management, ecological research and monitoring of fish

Although many of the rivers and fish communities in many sub-Alpine areas, such as those in Slovenia, are deemed to be 'pristine', a number of exotic, non-native fish species are present. This is due to the stocking of non-native fish over many years and is also common practice in many cases where recreational angling relies of regular stocking. Stocking is also often a common practice in lowland waters so as to increase the standing stock of fish, again mainly for the purpose of angling. Introduced species include Rainbow Trout (*Oncorhynchus mykiss*, deliberately released and economically important), Sun Perch (*Lepomis gibbosus*, an accidental release in ponds and artificial lakes), two species of catfish (Wels *Siluris glanis* from Europe and Black Bullhead *Ictalurus melas* from the USA), Grass Carp (*Ctenopharyngodon idella*) and Silver Carp (*Hypophthalmichthys molitrix*) which are both from the Far East. The latter two are fish species accidentally introduced alongside Carp. There are also some non-native populations of Arctic Char (*Salvelinus alpinus*) to mention just a few examples of changes that have occurred due to the introduction of non-native fish species or subspecies.

The Rainbow Trout is deliberately stocked and anglers do fish for it and eat it. Native fish species often have to be returned to the water but Rainbow Trout may be taken by anglers, although there are places where this species is not wanted. There is evidence that Rainbow Trout interact negatively with Grayling when introduced to the same waters (M Govedič pers. comm., for Brown Trout and Grayling see Mäki-Petäys *et al.* 2000). This further complicates the assessment of the role that predation by Cormorants plays; interspecific competition between fish predators was often mentioned as an important factor determining the overall development of the fish population. Added to this comes the effect of invasive species, whether they be fish, crustaceans or molluscs, on the fish fauna and this further complicates the assessment of any predatory effects by Cormorants.

The vulnerability of stocked fish to predation by Cormorants is largely unknown. Most likely the stocked fish, reared in captivity under artificial conditions are less wary and probably show little, or no, escape behaviour in response to the presence of a predator. This makes these modified waters additionally sensitive to predation. Cormorants on the other hand, are very well able to catch these fish (as are other predators). For the stocked fish themselves, the switch to foraging under natural conditions and a limited adaptation to naturally occurring diseases and parasites makes them additionally vulnerable and the question is how much the predation by Cormorants adds to the other factors causing mortality amongst such stocked fish. Apart from the difficulties of assessing any damage to fish stocks or populations by Cormorants in these systems, data on predation of these introduced fish cannot simply be used as surrogates for the situation in wild populations. Therefore it is very difficult to deduce mortality rates in wild fish from studies using released fish (e.g. tagged Salmon smolts [Jepsen *et al.* 2010] young sole *Solea* spp. and Eel in North Sea). The effect of stocking on other fish species is also relevant in this respect but has been little studied. The habit of stocking is thus of great importance with respect to the composition of the fish community.

One very important aspect of this work requiring consideration here is the lack of response to requests for quantitative fish data from large areas of continental Europe (e.g. inland France and Spain, but also coastal Denmark and Italy) in relation to some of the important countries holding large numbers of Cormorants. These areas form an important winter or summer habitat for Cormorants but, despite the best efforts of **INTERCAFE** researchers, very little information could be obtained either by reference to the published scientific literature or through direct enquiry to national experts. Fisheries institutes tend to focus mostly on the more rare, larger and most often commercially important species and consequently have less interest in a quantitative community approach that would include commonly occurring non-commercial species. Parallel to this trend in inland waters, much research effort in marine environments has been directed towards the deeper, offshore waters. Again, this is probably related to the ultimate commercial, rather than scientific, interest in these habitats/fish species. This paucity of 'fish community' data may perhaps be addressed through the Water Framework Directive, as monitoring and habitat quality assessment are prerequisites for the management schedules that have to be set-up in Europe.

12.2.4 What future ecological studies are needed?

INTERCAFE has compiled a considerable amount of new data in relation to Cormorant ecology, status and distribution. Thus a logical framework could be built by combining different sources of information and this allowed a cohesive ecological view on the interface between Cormorants and Human interests. This view will be discussed in detail in the final chapter of this publication.

Perhaps the most striking thing about **INTERCAFE's** work in this area was the commonly perceived lack of quantitative fish data for many water bodies. Although much emphasis has been placed on the gathering and validating Cormorant data (with respect to numbers, distribution, migration, food and population ecology), similar, analogous data are scarce or completely absent for most fish species or communities. This is all the more striking because, in many cases, the conflict between Cormorants and Man is played out (in even the 'best' cases), through what is essentially circumstantial evidence.

As discussed in detail in chapter 9 of the **INTERCAFE** Field Manual (Carss *et al.* 2012), accurate quantitative data on fish must be available before any significant effect of Cormorant predation (e.g. impact or damage to a fishery) can be demonstrated. This is especially true for the more natural, open and larger-scale water systems. In smaller reservoirs, ponds and fish farms, where fish populations are the result of repeated introductions, in combination with high density and limited possibilities for fish to seek cover and evade predation or migrate to other systems, the situation is more complex. In these cases, Cormorants may cause considerable effects, either by direct removal of fish or indirectly through increased mortality (e.g. physical damage to uneaten fish in the form of scars, stress, increased vulnerability to other predators and/or diseases/parasites). However, even in these cases it is not necessarily easy to judge or quantify 'damage' because relevant information about the management of such enterprises is not usually publically available, particularly in relation to the economics of the system/enterprise.

There is potential here for a serious debate over how best to measure Cormorant impact at fisheries (again see chapter 9 of Carss *et al.* 2012). If fish biology were better understood in a quantitative manner comparable to that of ornithological data, then it might be easier to conclude something about the extent to which damage (or at least an ecological interaction) occurs. Thus, if the next step in the process is to combine Cormorant and fish data and devise sophisticated models to forecast trends in Cormorant status and distribution in relation to a changing environment, for fishery data this would to a large extent mean the collection of basic raw data for different water systems. Currently there appears to be an enormous gap to bridge before it is possible to compare fish data with bird data at 'equal levels', particularly in relation to species composition, standing stock and production in relation to trophic state of the system, food chain relationships and studies on fish movement and migration.

It is obvious that this plea will not be followed by any action if there were no other drivers than just Cormorants. From a purely biological perspective (but there are others which may be equally, or even more, valid (see chapter 9 of Carss *et al.* 2012), in relation to Cormorant 'impact' at fisheries, quantitative ecological studies of fishes, including field estimates of natural mortality for different species are urgently needed if the distinction between additive and compensatory mortality is to be made. This is the basic question that is crucial in relation to the whole issue of Cormorant 'damage' or 'impact' at fisheries from a biological perspective. In other words, is the effect of Cormorant predation partly or fully compensated for by extra growth and/or lower mortality in the group of remaining fish? In currently applied fish models, the mortality factor is assumed to be constant, at best cohort-dependent, but accurate data from the field are completely lacking with regard to this. More realistic (and, at least, dynamic) models are needed to judge the effect of different predators (fish, birds, mammals, not to say also the individual species within these groups) in the same system. However, these models require sophisticated assessment of the relevant parameters. As discussed above, much of this information on fishes appears to be lacking for many of the systems (sites) where Cormorants are considered to be a problem for fisheries. Moreover, using incomplete or inadequate data from fisheries sustained by stocked fish that were reared in captivity (which tend to be those where relevant quantitative data are available) is of little use in this respect. Only if we were to possess fairly comparable data from above and under water, could the claims of damage in more natural systems be evaluated in any form of robust, scientific way.

However, as shown by the examples described extensively in this study, the impact of Cormorants is unlikely to have a direct effect on the composition and size of the fish stocks. There are a few exceptions and these are related to the fact that Cormorants can fly from one water body to another and fish can not. As the numerical relationship between Cormorants and their fish food-resource is probably set at the large scale of a geographical region, local concentrations of Cormorants may occur in some instances at locations which are have no, or only a few, birds most of the time. This is the case in pre-Alpine streams during periods of severe frost as most birds move away further south but at the same time some birds shift locations towards the remaining open (fast running) waters where they can exploit fish which are concentrated in these places. A similar, but still theoretical case could be the predation at isolated water bodies in areas where birds only pass through. Again, local bird numbers visiting such a site could be higher than is sustainable for the fish population there. At a larger scale than an individual water body, this mechanism may apply to the proposed 'watershed hypothesis', describing the relatively high level of complaints about damage by Cormorants in the upstream areas of an area grossly dividing the Baltic-North Sea-Atlantic Ocean on one hand and the Black Sea-Mediterranean on the other (see section 10.2). These areas may be especially susceptible to Cormorants that migrate through them to and from their breeding areas which tend to be in more lowland/coastal areas.

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.

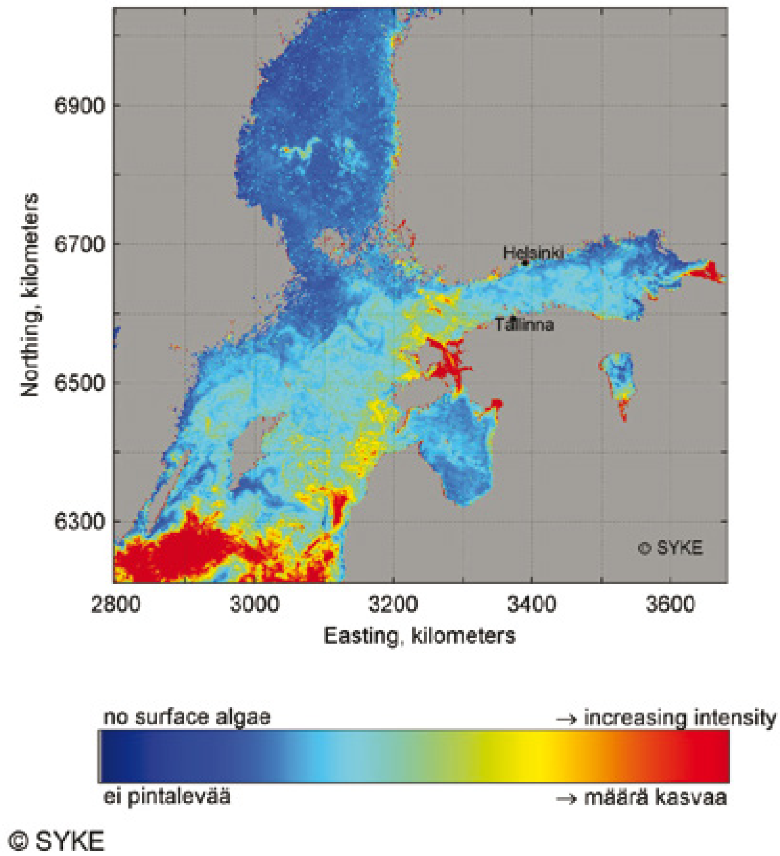


Figure 13.1 Example of algal blooms in the Baltic Sea as depicted by satellite images taken during summer 2006. More blooms occur in southern and shallow water areas. Notice also the apparent bloom in the southern part of Lake Peipsi, and that the southernmost (and most polluted) part (Lake Pskov) has 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

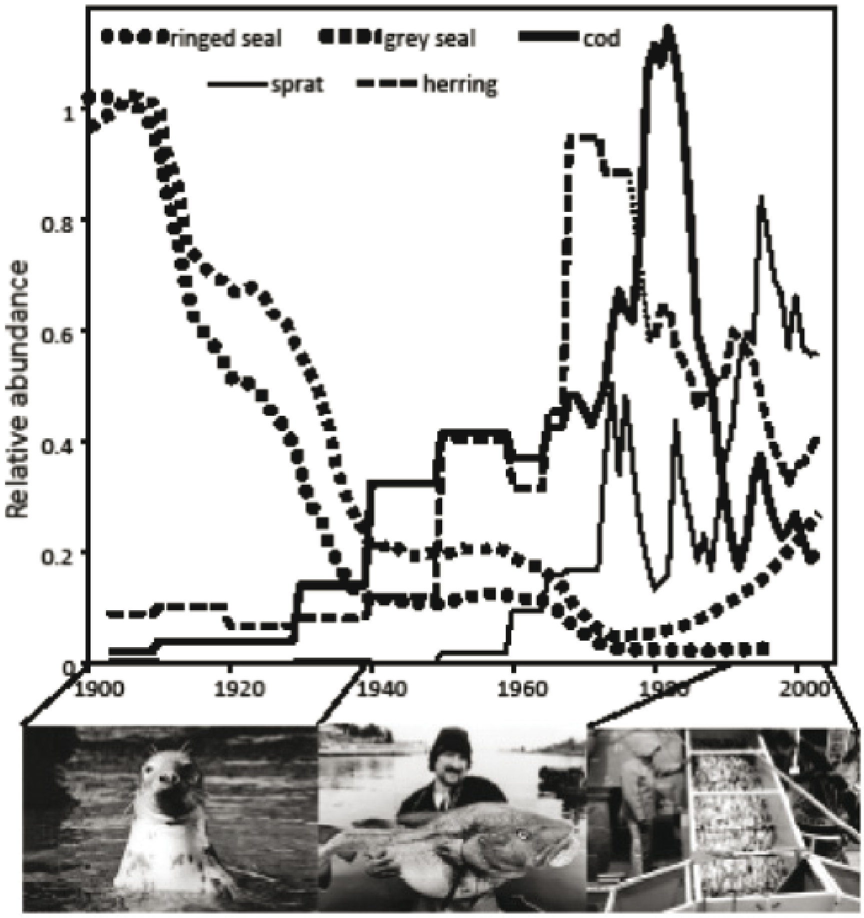


Figure 13.2 Long-term changes in catches and abundance of different key organisms in the Baltic (after Österblom *et al.* 2006) and trophic relationships between cod, sprat and plankton as well as the alternative predators pike and perch (right). The Cormorant's appearance since the mid 1990s runs parallel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

of over-fishing, is highly attractive to Cormorants.

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.

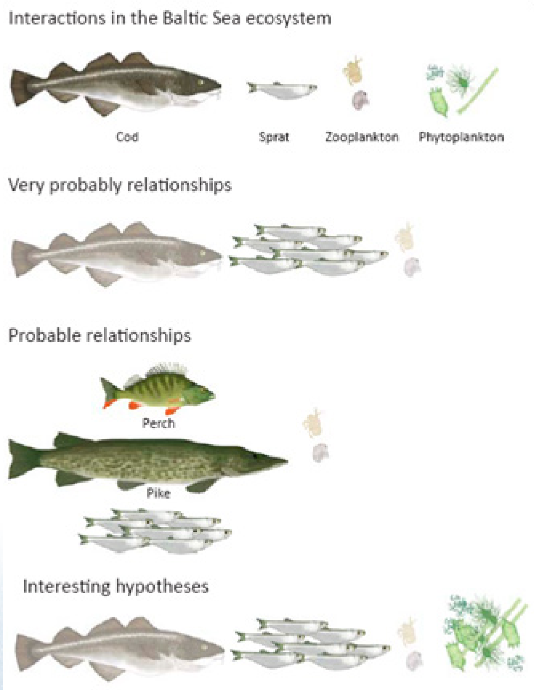


Figure 13.3 Relationships between Cod and other trophic levels in the Baltic Sea. (From Österblom 2009). The abundance of small fish (here Sprat) in all routes is providing favourable food conditions for Cormorants.

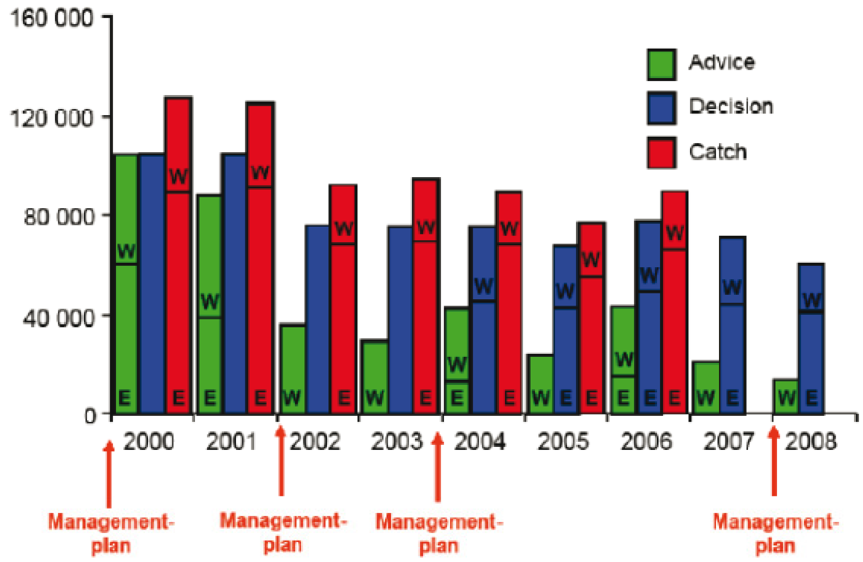


Figure 13.4 Over-fishing of Cod in the Baltic in recent times. After the strong decline in catches the 1980s, ICES advice on catches (green bars) has been consistently lower than the politically achieved decision on allowable catches (blue bars), whilst actual catches have been higher still (red bars).

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.

14 References

Alerstam, T. 1981. Bird Migration. Ecology Building, Lund.

Ardizzone, G S, Cataudella, and Rossi, R. 1998. Management of Coastal Lagoon Fisheries and Aquaculture in Italy. FAO Fisheries Technical Paper, No. 293.

Boldreghini, P, Volponi, S, Santolini, R, Cherubini G, and Utmar, P. 1997. Recent trend of the Cormorant population wintering in the Northern Adriatic. Ekologia Polska 45: 17–22.

Carss, D N. 2003 (ed). Reducing the conflict between cormorants and fishries on a pan-European scale: REDCAFE. Final Report to the EU, contract No. Q5CA-2000-31387, pp.169.

Carss, D N, and Marzano, M (eds.) 2005. Reducing the Conflict between Cormorants and Fisheries on a pan-European Scale (REDCAFE), Summary and National Overviews. Report (pp 374) to EU, contract No. Q5CA-2000–31387.

Carss, D N, Bell, S, and Marzano, M. 2009. Competing and Coexisting with Cormorants: Ambiguity and Change in European Wetlands. In Heckler, S (eds.) (2009). Landscape, Process and Power. Re-evaluating Traditional Environmental Knowledge. Volume 10, studies in environmental anthropology and ethnobiology. Berhanhn books USA ISBN 978-1-84545-549-1.

Carss, D N, Parz-Gollner, R, Trauttmansdorff, J (eds). 2012. The **INTERCAFE** Field Manual - research methods for cormorants, fishes and the interactions between them. **INTERCAFE** COST Action 635 Final Report II. ISBN 978-1-906698-08-9.

Cramp, S, and Simmons, K E L. (eds). 1977. The Birds of the Western Palearctic, Vol. 1. Oxford University Press, Oxford.

Eskildsen, J. 2006. Skarver 2006. Naturovervågning. Arbejdsrapport fra Danmarks Miljøundersøgelser No. 223.

Gandolfi, G, Loanilli, E, and Vitali, R. 1985. Caratteristiche biologiche delle cominità ittiche, studi sulle migrazioni ed aspetti quantitative delle attività alieutiche nel Delta del Po. Nova Thalassia, 7(suppl.2): 281–309.

Govedič, M. 2001. [Diets of cormorants (*Phalacrocorax carbo*) in region of Sava river between Ljubljana and Zagorje (Slovenia)]. Graduation Thesis, University of Ljubljana, Slovenia. In Slovenian.

Govedič, M, Janžekovič, F, and Kos, I. 2002. Prehrana kormorana *Phalacrocorax carbo* na območju reke Save od Ljubljane do Zagorja, (Slovenija) [The diet of Great Cormorants *Phalacrocorax carbo* on the Sava river between Ljubljana and Zagorje (Slovenia)]. Acrocephalus, Ljubljana 23 (110–111): 5–20.

Gutman M, Kaplan, D, and Gutman, R. 2001. Restoration and Conservation of Fauna and Flora in the Re-Flooded Hula Wetland in Northern Israel. LIFE - PROJECT No: LIFE TCY/97/1L/O38. Migal Galilee Technology Center. Kiryat Shemona.

Hanson, J M, and Leggett, W C. 1982. Empirical prediction of fish biomass and weight. Can. J. Fish. aquat. Sci. 39: 257–263.

Herrmann, C. 2007. Bestandsentwicklung und Kormoranmanagement in Mecklenburg-Vorpommern. BfN-Skripten 204, 48–71.

Hijmans, R J, Cameron, S E, Parra, J L, Jones, P G, and Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.

Hjerne, O, and Hansson, S. 2001. Constant catch or constant harvest rate? — The Baltic Sea cod (*Gadus morhua* L.) fishery as a modeling example. Fisheries Research 14: 57–70.

Jespen, N, Klenke, R, Sonnesen, P, and Bregnballe, T. 2010. The use of coded wire tags to estimate cormorant predation on fish stocks in an estuary. Marine and Freshwater Research 61:320–329.

Jeppesen, E, Jensen, J P, Søndergaard, M, Lauridsen, T, Junge Pedersen, L, and Jensen, L. 1997. Top-down control in freshwater lakes: the role of nutrient state, submerged macrophytes and water depth. Hydrobiologia 342/343: 151–164.

Johnsgard, P A. 1993. Cormorants, Darters, and Pelicans of the World. Washington: Smithsonian, 1993. Quarto, 445 pp. (ISBN: 1560982160) (EAN: 9781560982166).

Kirikova T, Gregersen, J, and Grinchenko, A. 2007. The development of the largest colony of the Great Cormorant (*Phalacrocorax carbo sinensis*) in Europe. Branta 10: 175–182.

Lammens, E H L, Kangur, A, Kangur, P, Melnik, M. 2007. Fish stock and fishery. In: van Eerden *et al*. (eds.). In the mirror of a lake: Peipsi and IJsselmeer for mutual reference. Rijkswaterstaat Waterdienst, Lelystad 2007.

Lehikoinen, A. 2006. Cormorants in the Finnish archipelago. Ornis Fennica 83: 34–46.

Limburg, K E, Walther, Y, Hong, B, Olson, C, and J. Storå 2008. Prehistoric versus modern Baltic Sea cod fisheries: selectivity across the millennia. Proc. Biol. Sci. 275: 2659–2665.

Maitland, P S, and Campbell, R N. 1992. Freshwater Fishes of the British Isles.The New Naturalist Series, published by Harper Collins.

Mäki-Petäys, A, Vehanen, T, and Muotka, T. 2000. Microhabitat Use by Age-0 Brown Trout and Grayling: Seasonal Responses to Streambed Restoration under Different Flows. Transactions of the American Fisheries Society 2000; 129: 771–781.

Martyniak, A, Mellin, M, Stachowiak, P, and Wittke, A. 1997. Food Composition of Cormorants *Phalacrocorax carbo* in two colonies in North-east Poland. Ekologia Polska, 45: 245–245.

Martyniak, A, Wziątek, B, Szymańska, U, Hliwa, P, and Terlecki, J. 2003. Diet composition of Great Cormorants *Phalacrocorax carbo sinensis* at Kąty Rybackie, NE Poland, as assessed by pellets and regurgitated prey. Vogelwelt 124, Suppl.: 217–225.

Marzano, M, and Carss, D N. (2012). Essential social, cultural and legal perspectives on Cormorant-fisheries conflicts. COST 635 Final Report IV. ISBN 978-1-906698-11-9.

Navodaru, I. 2001. Seaward drift of the Pontic Shad larvae (*Alosa pontica*) and the influence of Danube river hydrology on their travel path through the Danube delta system. Bull. Fr. Pêche piscic. (2001) 362–363: 749–760.

Nelson, J B. 2005. Pelicans, Cormorants and Their Relatives: Pelecanidae, Sulidae, Phalacrocoracidae, Anhingidae, Fregatidae, Phaethontidae. Oxford University Press. pp.162–163. ISBN 0198577273.

Newson, S E, Marchant, J, Ekins, G R, and Sellers, R M. 2007. The status of inland-breeding Great Cormorants in England. British Birds 100: 289–299.

Ostendorp, W, Iseli, C, Krauss, M, Krumscheid-Plankert, P, Moret, J-L, Rollier, M, and Schanz, F. 1995. Lake shore deterioration, reed management and bank restoration in some Central European lakes. Ecol. Engineering 5: 51–75

Österblom, H, Casini, M, Olsson, O, and Bignert, A. 2006. Fish, seabirds and trophic cascades in the Baltic Sea. Mar. Ecol. Prog. Ser. 323: 233–238

Österblom, H. 2009. (ed.) The role of Cod in the Baltic Sea, Baltic Sea 2020, Stockholm, report, 27pp.

Pauly, D, Christensen, V, Dalsgaard, J, Froese, R, and Torres, R Jr. 1998. Fishing Down Marine Food Webs. Science 279: 860–863.

Post, J, Sullivan, M, Cox, S, Lester, N, Walters, C, Parkinson, E, Paul, A, Jackson, L, and Shuter, B. 2002. Canada's recreational fisheries: the invisible collapse? Fisheries, 27, (1), pp.6–17.

Platteeuw, M, Kiss, J B, Zhmud, M Y, and Sadoul, N. 2004. Colonial waterbirds and their habitat use in the Danube Delta: as an example of a large-scale natural wetland. *RIZA report 2004.002*. Directorate-General for Public Works and Water Management: Danube Delta Institute. ISBN 90-369-5658-7, 168pp.

Przybył, J. 1994. Kormoran — Twój wróg? [Cormorant — your enemy?]. Przegląd Rybacki 19 (4): 25–38 (in Polish).

Russell, I R, Broughton, B, Keller, T, Carss, D N. 2012 The **INTERCAFE** Cormorant Management Toolbox — methods for reducing cormorant problems in European fisheries. ISBN 978-1-906698-09-6. **INTERCAFE** COST 635 Final Report III.

Quiros, R. 1990. Predictors of relative fish biomass in lakes and reservoirs of Argentina. Can. J. Fish. aquat. Sci. 47: 928–939.

Scheffer, M, Carpenter, S, and Young, B. 2005. Cascade effects of over-fishing marine systems. Trends in Ecology and Evolution 20: 579–581.

Scheffer, M. 1998. Ecology of Shallow Lakes. Chapman and Hall, London, 357pp.

Schratter, D, and Trauttmansdorff, J. 1993. Kormorane *Phalacrocorax carbo sinensis* an der Donau und Enns in Österreich: Analyse der Speiballen. Orn. Verh. 25: 129–150.

Seiche, K, Gerdeaux, D, Gwiazda, R, Lévai, F, Nemenonoks, O, Strod, T, and Carss, D. 2012. Cormorant-fisheries conflicts at Carp ponds in Europe and Israel — an **INTERCAFE** overview. COST 635 Final Report V. ISBN 978-1-906698-10-2.

Shmueli, M, Izhaki, I, Arieli, A, and Arad, A. 2000. Energy requirements of migrating Great White Pelicans *Pelecanus onocrotalus*. Ibis 142: 208–216

Shurulinkov, P, Nikolov, I, Demerdhiev, D, Bedev, K, Dinkov, H, Dakalova, G, Stoyhev, S, Hristov, I, and Ralev, A. 2007. Die aktuelle brutverbreitung und die bestände Reiher und Cormorane in Bulgarien. Ornitologische Mitteilungen 11: 370–378.

Staav, R. 2007. Storskarven i Sverige. Resultat från riksinventeringen 2006. SOF 2007. *Fågelåret 2006*. Stockholm.

Stempniewicz, L, Martyniak, A, Borkowski, W, and Goc, M. 2003a. Fish stocks, commercial fishing and cormorant predation in the Vistula Lagoon, Poland. In: Cowx, I G. (ed.) Interactions between fish and birds: implications for management. Blackwell Science Ltd, Oxford: 51–64.

Stempniewicz, L, Martyniak, A, Borkowski, W, and Goc, M. 2003b. Interrelationships between Ruffe *Gymnocephalus cernuus* and Great Cormorants *Phalacrocorax carbo sinensis* in the Vistula Lagoon, N. Poland. Vogelwelt 124, Suppl.: 261–269.

Strod, T, Arad, Z, Izhaki, I, and Katzir, G. 2004. Cormorants keep their power: visual resolution in a pursuit-diving bird under amphibious and turbid conditions. Curr. Biol. 14, R376–R377.

Susnik S, Snoj, A, and Dovc, P. 2001. Evolutionary distinctness of grayling (*Thymallus thymallus*) inhabiting the Adriatic river system, as based on mtDNA variation. Biol. J. Linn. Soc. 74: 375–385.

Suter, W. 1991. Der Einfluss fishfressender Vogelarten auf Süsswasserfisch-Bestände eine Ubersicht. J. Orn., 132, 29–45.

SYKE (Finnish Environment Institute). 2006. Cormorant populations still growing in the Archipelago Sea and the Gulf of Bothnia. Press release, 08/16/2006, http://www.environment.fi

Trauttmansdorff, J, and Wassermann, G. 1995. Number of pellets produced by immature Cormorants *Phalacrocorax carbo sinensis*. Ardea 83: 133–134.

van Dam, C, Buijse, A D, Dekker, W, van Eerden, M R, Klein, J G P, Breteler, and Veldkamp, R. 1995. Aalscholvers en beroepsvisserij in het IJsselmeer, het Markermeer en Noordwest Overijssel. Informatie en Kenniscentrum Natuurbeheer, Wageningen. Report nr. 19, 104pp.

van Eerden, M R. 1997. Patchwork; Patch use, habitat exploitation and carrying capacity for water birds in Dutch freshwater wetlands. PhD thesis Groningen University and Van Zee tot Land 65, Rijkswaterstaat Directorate IJsselmeergebied, Lelystad 448p.

van Eerden, M R, and Voslamber, B. 1995. Mass fishing by Cormorants *Phalacrocorax carbo sinensis* at lake IJsselmeer, The Netherlands: a recent and successful adaptation to a turbid environment. Ardea 83:199–212.

van Eerden, M R, van Rijn, S, and Noordhuis, R. 2003. How Zebra Mussels Dreissena polymorpha, Smelt *Osmerus eperlanus* and commercial fisheries interact with Great Cormorants *Phalacrocorax carbo sinensis* in Lake IJsselmeer: the food web cascade revisited. Vogelwelt 124: 227–290.

van Eerden, M R, van Rijn, S, Millers, K, Lilleleht, V, and Kilpi, M. 2007. Cost **INTERCAFE** Short Term Scientific Mission Estonia, Gulf of Finland 16–24 June 2007.

van Nes, E H, Lammens, E H R R, and Scheffer, M. 2002.

PISCATOR, an individual-based model to analyze the dynamics of lake fish communities. Ecol. Modell. 152: 261–278.

van Rijn, S H M, and Van Eerden, M R. 2002. Aalscholvers in het IJsselmeergebied: concurrent of graadmeter? Vogels, vissen en visserij in duurzaam evenwicht. RIZA rapport 2001.058. Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling, Lelystad.

van Rijn, S H M, and van Eerden, M R. 2007. Recent population changes of Cormorants (*Phalacrocorax carbo*) in the IJsselmeer area, the Netherlands. Aves 44 2007: 151–154.

Volponi S. 1997. Cormorants wintering in the Po Delta: estimates of fish consumption and possible impact on aquaculture production. Suppl. Ric. Biol., Selvaggina, XXVI: 323–332.

Volponi, S, and Rossi, R. 1995. Predazione degli uccelli ittiofagi in acquacoltura estensiva: valutazione dell'impatto e sperimentazione di mezzi di dissuasione incruenta. Biologia Marina Mediterranea, 5: 1375–1384.

Volponi, S, and Callegarini, P. 1997. Osservazioni sul regime alimentare del Cormorano (*Phalacrocorax carbo sinensis*) nel Delta del fiume Po nella stagione 1993/94. Laguna, 1: 32–39.

Wahlström, E, Hallanaro, E-L, and Manninen, S. 1996. The Future of the Finnish Environment. Published by Edita for the Finnish Environment Institute, Helsinki.

Wetlands International Cormorant Research Group (WI-CRG) 2008. Cormorants in the western Palearctic. Explanatory brochure, pp.4. Available at: http://ec.europa.eu/environment/nature/cormorants/files/Leaflet_CRG_Count_2003-2006.pdf

Witteveen and Bos (ed.) 2008. Bureaustudie invlioed Aalscholvers IJsselmeer en Markermeer op visstand en beroepsvisserij (in Dutch). Witteveen+Bos Deventer.

Witteveen and Bos (ed.) 2009. Metingen vismigratie via de spuicomplexen in de Afsluitdijk. Report 1696-1 (in Dutch), Rijkswaterstaat IJsselmeergebied, Lelystad, 88pp.

REFERENCES USED FOR WATER SYSTEMS DATABASE

Bouchard, P, Chappaz, R, Cavalli, L, and Brun, G. 1998. Influence of environmental variables on the growth of *Leuciscus cephalus* (Linnaeus, 1766) in the river Durance, South-east France. Annls Limnol. 34(2): 193–200.

Bzoma S. 1998. The contribution of round goby (*Neogobius melanostomus* Pallas 1811) to the food supply of cormorants (*Phalacrocorax carbo* Linnaeus 1758) feeding in the Puck Bay. Bulletin Sea Fisheries Institute 2 (144): 39–47.

Bzoma S, Goc, M, Brylski, T, Stempniewicz, L, and Iliszko, L. 2003. Seasonal changes and intra-colony differentation in the exploitation of two feeding grounds by great Cormorants *Phalacrocorax carbo sinensis* at Kąty Rybackie (N. Poland). Vogelwelt 124, Suppl.: 175–181.

Campos, F, and Lekuona, J M. 1994. La población invernante de Cormorán Grande (*Phalacrocorax carbo*) en el norte de España y suroeste de Francia. Ardeola 41 (1): 13–18.

Costa, M J, Vasconcelos, R, Costa, J L, and Cabral, H N. 2007. River flow influence on the fish community of the Tagus estuary (Portugal). Hydrobiologia 587, 113–123.

Dalsgaard, A J, Christensen, V, Nicolajsen, H, Koed, A, Støttrup, J, Grooss, J, Bregnballe, T, Sørensen, H-L, Christensen, J T, Nielsen, R. 2008. Økosystemmodel for Ringkøbing Fjord. Report 100, DTU.

Danmarks Fiskeriundersøgelser, 2003: Notat vedrørende fiske-bestanden i området nord for Fyn.

Dikov and Živkov. 2004. Abundance and biomass of fishes in the Veleka River, Bulgaria. Folia Zoologica 53(1): 81–86.

Đordevič, V, Mikuska, J. 1986. Influence of the cormorant on the culture of fish on the fish farm PIK Belje; Ribarstvo Jugoslavije, 41: 74–76.

Engström, H. 2001. Effects of Great Cormorant predation on fish populations and fishery. PHD thesis, Uppsala University, Sweden.

Gassner, H, and Wanzenböck, J. 1999. Hydroakustische Fisch-bestandserhebungen in vier Salz-kammergutseen. Österreichs Fischerei 52; 122–128.

Gmitrzuk, K. 2004. Influence of cormorant *Phalacrocorax carbo* on water and forest ecosystems of Wigierski National Park. Parki Narodowe i Rezerwaty Przyrody 23 (1): 129–146 (in Polish with English summary).

Gwiazda, R. 2006. Foraging strategies of fish-eating birds in conditions of artificial reservoirs in southern Poland. Studia Naturae 51: 1–112 (in Polish with English summary).

Haunschmid, R. 2009. Unter-suchung der Fischbestände in ausgewählten Salzburger Gewässern in Hinsicht auf den Einfluss durch Graureiher und Kormoran. Amt der Salzburger Landesregierung, Endbericht 2008, 72p.

Hoffman, E. 1968. En unders-øgelse af skrubbens (*Plathichthys flesus* L.) frugtbarhed og gydning, og den hermed forbundne konditionscyklus. Specialerapport Danmarks Fiskeriundersøgelser.

Honsig-Erlenburg, W, and Friedl, T. 1997. Einfluss des Kormorans auf die Fischbestände der mittleren Gail (Kärnten). Österreichs Fischerei 50, 113–117.

Jungwirth, M, Muhar, S, Zauner, G, Kleeberger, J, and Kucher, T. 1996. Die Steirische Enns-Fischfauna und Gewässermorphologie. Universität für Bodenkultur, Abteilung Hydrologie, Fischereiwirtschaft und Aquakultur, Wien 260pp.

Kainz, E, and Gollmann, P. 2001. Beobachtungen über Fisch-bestandsänderungen in einer Restwasserstrecke ÖF 54, 190–204.

Limfjordsovervågningen for Nordjyllands, Viborg og Ringkjøbing Amter, 2002: Fiskeriundersøgelser med yngeltrawl på lavt vand i den vestlige Limfjord, 2001.

Lorentsen, S-H, Grémillet, D, and Nymoen, G H. 2004. Annual variation in diet of breeding great cormorants: does it reflect varying recruitment of gadoids? Waterbirds 27, 161–169.

Marion, L, and Marion, P. 1984. La nidification du Grand-cormoran *Phalacrocorax carbo* au lac de Grand-Lieu : premier cas d'une reproduction continentale réussie en France. L'Oiseau & Revue Française Ornithologie 54: 267–271.

Marion, L. 1995. Where two species meet: origin, habitat choice and niche segregation of Cormorant *Phalacrocorax c. carbo* and *Ph. c. sinensis* in the common wintering area (France), in relation with breeding isolation in Europe. Ardea 83: 103–114.

Marion, L. 1998. Comparison between the diet of breeding Cormorants *Phalacrocacax carbo sinensis*, captures by fisheries and available fish species: the case of the largest inland colony in France, at the Lake of Grand-Lieu. Suppl. Ric. Biol. Selvaggina 26: 313–322.

Marion, L. 1999. Le Lac de Grand-Lieu. SNPN, Paris: 64p.

Marion, L, Marion, P, Reeber, S, Carpentier, A, and Pont, Y. 2000. Dynamique de population et impact alimentaire de la colonie de Grands cormorans du Lac de Grand-Lieu. Ministère Environnement, MNHN et Univ. Rennes: 73p.

Mathieu, L, and Gerdaux, D. 1998. Etude comparee du regime alimentaire du Grand Cormoran *Phalacrocorax carbo sinsensis* sur les lacs Leman, d'Annecy et du Bourget. Nos Oiseaux 45: 163–171.

Mellin, M. 1990. Preliminary results of the dissection of Cormorants shot in the Mazurian Lakeland in spring 1987. Notatki Ornitologiczne 31 (1–4): 53–59 (in Polish with English summary).

Mellin, M, and Mirowska-Ibron, I. 2002. Population trend of great Cormorant in the north-eastern part of Poland with respect to fishpond areas. In: Der Kormoran (*Phalacrocorax carbo*) im Spannugsfeld zwischen Naturschutz und Teichbewirtschaftung 1, Sachsisxche Landesstiftung Natur und Umwelt: 51–55.

Mikuska, J. 1983. Contribution to the knowledge of the feeding habits of the Cormorant in the Kopačevski rit Zoological Reservation; Larus 33–35: 31–36. Zagreb.

Myndighedssamarbejdet mellem staten og Limfjordsamterne om fiskeriet i Limfjorden, 2000: Fiskeundersøgelser i Limfjorden 1999.

Neves, A, Cabral, H, Figueiredo, I, Sequeira, V, Moura, T, and Gordo, L S. 2008. Fish assemblage dynamics in the Tagus and Sado estuaries (Portugal). Cahiers de Biologie Marine, 49: 23–35.

Nielsen, E, and Bagge, O. 1985. Preliminary investigations of 0-and 1-group plaice surveys in the Kattegat in the period 1950-84. DF&H-report No. 268.

Nienhuis, J. 1997. Food choice of non-breeding cormorants in Matsalu bay in spring: are cormorants and smews competitors? Matsalu Looduskaitseala, Loodusvaatlusi 95/96: 33–42.

Opačak, A, Florijančić T, Horvat, D, Ozimec, S, and Bodakoš, D. 2004. Diet spectrum of great cormorants at the Donji Miholjac carp fishponds in Eastern Croatia; Eur. J. Wild. Res. 50: 173–178.

Parz-Gollner, R, and Trautt-mansdorff, J. 2003. Kormoran — Monitoring Niederösterreich 2001/2002 und 2002/03. Inst. f. Wildbiol.u.Jagdwirtschaft, Uni.f. Bodenkultur. Auftrag der NÖ Landesreg., 70p + Anhang.

Przybysz, J. 1997. Kormoran. Wyd. Lubuskiego Klubu Przyrodników, Świebodzin: 108 pp (in Polish with English summary).

Ringkjøbing Amt. 1968. Ringkøbing Fjord. Fiskebestanden 1967.

Ringkjøbing Amt. 1998. Ringkøbing Fjord. Fiskebestanden 1997.

Ringkjøbing Amt. 2000a. Ringkøbing Fjord. Fiskebestanden 1999.

Ringkjøbing Amt. 2000b. Ringkøbing Fjord. Fiskeæg og fiskelarver foråret 2000.

Skarprud, M. 2003. Summer food of great cormorant *Phalacrocorax carbo* in Øra Nature Reserve, Fredrikstad. MSc Thesis, the Agricultural University of Norway, ÅS.

Steiner, V. 1999. Fischökologische Beweissicherung ENNS, Stauraumspülung KW Sölk 1999. 1.Zwischenbericht - IST ZUSTAND VOR DER SPÜLUNG- im Auftrag der Steweag/Graz, Volker Steiner — Institut für Fischforschung — 6020 Innsbruck.

Tomiałójč L, and Stawarczyk, T. 2003. The Avifauna of Poland. Distribution, numbers and trends. I. PTPP 'Pro Natura', Wrocław: 75–79 (in Polish with English summary).

Veber, T. 2001. Kormoranide ja kalanduse vahelised interaktsioonid Eesti rannikumeres. Magistritöö. Tartu Ülikool.

Wziątek, B, Martyniak, A, Szymańska, U, Kozłowski, J, and Dostatni, D. 2003. Composition of Great Cormorant *Phalacrocorax carbo sinensis* diet in the Dravien National Park, NW-Poland. Vogelwelt 124, Suppl.: 291–295.

Zauner, G. 1999. Untersuchung des Einflusses durch Kormorane auf die fischereilichen und fischökologischen Verhältnisse der Enns, Bereich Liezen bis Gstatterboden. Univ.f.Bodenkultur Wien, Abt. Hydrobiologie, Fischereiwirschaft und Aquakultur. Studie im Auftrag des Amt der Stmk Landesregierung, 58p.

Zauner, G. 2002. Überprüfung des Kormoraneinflusses auf die fischereilichen und fischökologischen Verhältnisse der Donau in der Wachau. University of Natural Resources and Applied Life Sciences, Vienna.

REFERENCES USED FOR OVERVIEW OF STATUS OF CORMORANT IN EUROPE

Boertmann, D, and Mosbech, A. 1997. Breeding distribution and abundance of the great cormorant *Phalacrocorax carbo carbo* in Greenland. Polar Research 16 (2): 93–100.

Crowe, O. 2005. Ireland's Wetlands and their Waterbirds: Status and Distribution. Birdwatch Ireland.

Marion, L. 2008. Recensement national des Grands Cormorans nicheurs en France en 2006. Alauda 76: 135–146.

Mavor, R A, Pickerell, G, Heubeck, M, and Thompson, K R. 2001. Seabird numbers and breeding success in Britain and Ireland, 2000. Joint Nature Conservation Committee.

Mitchell, P I, Newton, S F, Ratcliffe, N, and Dunn, T E. 2004. Seabird Populations of Britain and Ireland. Poyser.

Paquet, Jean-Yves et la centrale ornithologique aves 2002. Le Développement de l'hivernage dus Grand Cormoran (*Phalacrocorax carbo*) en Wallonie et à Bruxelles entre 1990 et 2003. Aves 39/3–4 (2002).

Røv, N, and Paneva, T D. 2000. Great Cormorant *Phalacrocorax carbo*. S. 30-33 i: Anker-Nilssen, T, Bakken, V, Strøm, H, Golovkin, A N, Bianki, V V, and Tatarinkova, I P. (red.). The Status of Marine Birds Breeding in the Barents Sea Region. Norsk Polarinstitutt Rapportserie Nr. 113. Norwegian Polar Institute, Tromsø.

Schifferli, L, Burkhardt, M, and Kestenholz, M. 2005. Bestand-sentwicklung des Kormorans *Phalacrocorax carbo* in der Schweiz 1967-2003. Der Ornitholgische beobachter 102: 81–96.

van Rijn, S, and Nienhuis, J. 2004. Aalscholvers op slaapplaatsen in Nederland in Januari 2003 en 2004. Limosa 77: 1–4.

Wahl, J, Keller, T, and Sudfeldt, C. 2004. Distribution and numbers of the Great Cormorant *Phalacrocorax carbo* in Germany in January 2003 — results of the pan-German night roost census. Vogelwelt 125: 1–10 (2004).

Worden, J, Hall, C, and Cranswick, P A. 2004. Cormorants *Phalacrocorax carbo* in Great Britain: results of the January 2003 roost survey. The Wildfowl and Wetlands Trust, Slimbridge.

REFERENCES USED FOR GIS AND OTHER WORK

Hijmans, R J, Cameron, S E, Parra, J L, Jones, P G, and Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965–1978.

Ardizzone, G, Cataudella, S, and Rossi, R. 1998. Management of Coastal Lagoon Fisheries and Aquaculture in Italy. FAO Fisheries Technical Paper no. 293.

Lilleleht, V. 2006. Kormorani levik ja arvukus Eestis 2006. Jahinduse alamprogrammi projekti nr. 33 rakendusuuringu aruanne. Tartu 2006.

Volponi, S. 1997. Cormorants wintering in the Po Delta: estimates of fish consumption and possible impact on aquaculture production. Suppl. Ric. Biol., Selvaggina, XXVI: 323–332.

15 APPENDIX: WORK GROUP 1 MEMBERSHIP

The INTERCAFE Work Group 1 met and undertook work at each of the stakeholder meetings and during the between-meeting periods. Over the four-year span of INTERCAFE, the participants listed below attended some or all of the Group's meetings and contributed greatly to them. INTERCAFE participants from other Work Groups also made presentations and contributions to Work Group 1 meeting, but are not named individually here.

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This book may be cited as van Eerden, M, van Rijn, S, Volponi, S, Paquet, J-Y and Carss, D N. Cormorants and the European Environment: exploring Cormorant ecology on a pan-European scale. **COST** Action 635 Final Report I. ISBN 978-1-906698-07-2

EUROPEAN SCIENCE FOUNDATION

ESF provides the COST Office through an EC contract

COST is supported by the EU RTD Framework programme

Published by: NERC Centre for Ecology & Hydrology on behalf of COST

CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE ENVIRONMENT

Short Title: COST Action 635 Final Report I

Year of Publication: 2012

ISBN 978-1-906698-07-2

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