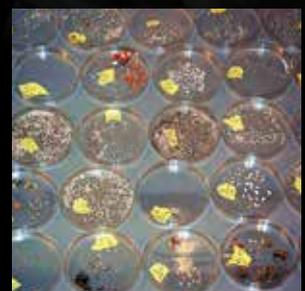


The INTERCAFE Field Manual

Research methods for Cormorants, fishes,
and the interactions between them



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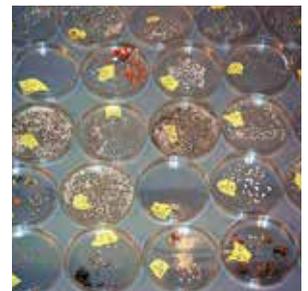


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Research methods for Cormorants, fishes,
and the interactions between them



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Dave Carss, Rosemarie Parz-Gollner & Josef Trauttmansdorff



ACKNOWLEDGEMENTS

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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 status and distribution 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, 'The **INTERCAFE** Field Manual' is a review of the methods used by researchers to study the ecology of both Cormorants and fishes, and an exploration of how such bird and fish datasets can be combined and compared in a useful and biologically meaningful way.

The **INTERCAFE** Field Manual has evolved organically over a long gestation period. The original idea to write a 'Cormorant Manual' emerged during late-night meetings of several participants at the 4th European Conference on Cormorants in Bologna, Italy, in November 1995. Here, there was a workshop on methods of studying diet and feeding ecology Chaired by DNC. This meeting was inspirational and brought together 28 researchers from 12 countries



Photograph — Shutterstock

across Europe, north Africa and Israel who sat for many hours around a large table and drafted a paper that was subsequently published as Carss *et al.* (1997).

After the meeting, several people focussed on writing specific texts which were then circulated to all for comments before being sent to independent reviewers for refereeing. Finally, the sections were combined together with a running narrative and the final review paper emerged. The aim of this paper was to ‘get our house in order’ by discussing the various methods of diet and food intake assessment.

To one of us (DNC), the writing process behind this move ‘towards a consensus view’ demonstrated that a relatively large number of international researchers (from very diverse biological, ecological and national backgrounds) could work together very effectively and, importantly, that the final product was greater than the sum of its constituent parts. It was from this collaboration that the seed to develop the REDCAFE Concerted Action (2000–01) was born, a piece of work that led logically to the **INTERCAFE COST** Action 3 years later. Whilst various issues of Cormorant ecology — and the rigorous study of it — were being discussed in Bologna, there was much discussion on scientific methodologies. One oft-voiced wish during those days was that it would be extremely useful for the research community (both established researchers and those starting to work on Cormorants) if all the standard methods used to study Cormorant numbers, diet, food intake, energy budgets,

demography, movements and migration could be described in a ‘Cormorant Manual’. Neither the aftermath of the WI-CRG Bologna meeting nor the REDCAFE project yielded ‘the Manual’ but the idea was not forgotten. It is to Josef Trauttmansdorff’s eternal credit that he resurrected the notion of the Manual in the early days of **INTERCAFE** and — alongside Rosemarie Parz-Gollner in particular but several other key writers (authorship is given alongside each chapter) — worked tirelessly towards its fruition.

The original idea of the Manual — to summarise the methods used by Cormorant researchers to (i) show others clearly how the research is done and (ii) to try to standardise these methodologies amongst the research community — was developed by **INTERCAFE** in three important ways.

First, quite a bit of background was added to the texts on the methods used to study Cormorant ecology. The idea here was that even if readers had no intentions of undertaking any studies themselves, they could gain a strong understanding of the complexities facing researchers who were involved in such work. The questions researchers are trying to answer are often very simple but the scientific, methodological, practical, temporal and financial constraints they inevitably face are seldom so. Thus, as well as an attempt to standardise methodological best practice (to minimise bias, improve validity, and make studies comparable), Part One of the Field Manual also became an attempt to explain how

Cormorant researchers do the work they do and how they understand the inevitable limitations of their work and the level of confidence they have in their ‘results’.

Second, much Cormorant research across Europe and beyond is undertaken (and funded, if funds are available) because the increasing numbers and expansion of the birds’ geographical range across Europe has raised serious concerns amongst representatives of many fisheries sectors. Indeed, many who catch fish for commercial reasons and/or pleasure believe that Cormorants are having harmful effects on their business and way of life (van Eerden *et al.* 2003: 11). Thus the idea was developed to include fisheries methods in the Field Manual to complement that of Cormorant research. This information was not needed here in relation to standardising methods as much has already been accomplished in the world of fisheries research. Instead, the emphasis here is on explaining to the interested reader how fisheries researchers do the work they do and how they understand the inevitable limitations of their work and the level of confidence they have in their ‘results’. This fisheries research information is described and discussed throughout much of Part Two of the Field Manual.

Third, and perhaps most difficult, was the desire to explore and discuss how Cormorant and fisheries data are integrated. Such integration is fundamental to an understanding of how Cormorant predation might ‘impact’ on fisheries interests and, as pointed out by van Eerden *et al.* (2003), this impact has been

the driver of much research effort. Nevertheless, such integration of bird and fish data is notoriously difficult to undertake with a high degree of ‘scientific’ confidence. Thus the final chapter of ‘The **INTERCAFE** Field Manual — research methods for Cormorants, fishes, and the interactions between them’ explores attempts to combine Cormorant and fish data, suggests how best to make progress in this field, and discusses how these two perspectives might be integrated.

The contents of the Field Manual are not carved on stone. It is anticipated that current methods may be refined and new ones developed as technology constantly improves and becomes available. Like Carss *et al* (1997), this publication should be seen as a

‘starting point’, nevertheless, it is a serious attempt (i) to describe the current methods used by Cormorant researchers and to help and encourage others in this field, (ii) to discuss the most commonly used research methods in relevant areas of fisheries science, and (iii) to describe the not insignificant problems researchers face when attempting to integrate such data.

Like all such endeavours, this publication is the result of the joint efforts of a number of researchers during the **INTERCAFE** Action. 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 above), as well as from the literature and unpublished data. Of particular benefit was the opportunity

to integrate information from numerous different sources and to collate knowledge and experience on a pan-European (and even global) scale and this is undoubtedly a unique strength of the work of the **INTERCAFE** Action.

INTERCAFE’s Work Group 1 produced two main outputs, this publication provides an overview of common methods and techniques used in Cormorant-fish studies and which formed the basis of much of the quantitative data collated and discussed in the other WG1 output. The other WG1 output ‘Cormorants and the European Environment: exploring Cormorant ecology on a continental scale’ (van Eerden, van Rijn, Volponi, Paquet & Carss 2012) provides the results of the main analysis of ecological aspects in relation to European Cormorants.

2 INTRODUCTION

Part One — Working with Cormorants

D N Carss and J Trauttmansdorff

This part of the **INTERCAFE** Field Manual is devoted to a critical review of field and laboratory methods used in scientific research on Cormorants. It aims to offer the reader the best practical advice on how to use these methods, understand their limitations, and maximise their usefulness. As well as promoting the use of standardised research methodologies, it is also hoped that the reader will also gain a better understanding of the research work required to answer such deceptively simple questions as ‘How many Cormorants are there?’ and ‘What do Cormorants eat?’.

This Field Manual is seen as being a starting point for standardising and improving Cormorant research methods rather than being the last word. All of the methods documented here are currently used by researchers but sometimes in slightly different forms. Many of them are based on common sense, detailed understanding of the species’ natural history and a basic knowledge of the sorts of things that are feasible in the field. Furthermore, methods are usually devised so that the subsequent data collected can be analysed in some statistically meaningful way. One of the important questions from this perspective is whether

an absolute estimate of numbers of Cormorants (or fishes, see chapter 8) is required or whether a ‘relative index’ is sufficient. Both can measure changes through time but only an absolute estimate tells researchers how many animals are in a particular site. Field workers must also consider what the data they collect will be used for — a reliable index is more useful to researchers than a poorly conducted count. It may not be necessary to count all the Cormorants (or fishes) at a site to obtain an estimate of the total size of the population. Thus field workers need to consider sampling — it may often be more effective to survey representative samples of the population and to extrapolate these results to obtain an estimate of the entire population. Clearly, samples should then be selected by non-subjective means, as those selected for convenience (for example) can have serious drawbacks. It is thus recommended that field researchers consult some of the widely available texts on biological sampling and statistical analyses wherever necessary.

In addition, the research techniques described in this part of the Field Manual explain the intensive work required to investigate Cormorant

population dynamics — how Cormorant numbers change over both time and geographical range, including how researchers investigate the movements of the birds. The following sections give (a) a brief overview of the ecology of the Great Cormorant and its relationship with humans and (b) some very important words of warning about Health and Safety and other practical issues associated with much of the field and laboratory work described in this Field Manual.

2.1 The Great Cormorant (*Phalacrocorax carbo*)

The Great Cormorant (*Phalacrocorax carbo*) is one of 65 bird species from six families that make up the order *Pelecaniformes*. This order includes the pelicans, gannets and boobies, Cormorants and shags, the Anhinga and the darter (‘snakebirds’), frigatebirds and tropic birds. Full descriptions of all species in this order, as well as their comparative biology, full ecological and behavioural reviews discussions of their relationships with man are given in two excellent books: *Cormorants, Darters and Pelicans of the World* (Johnsgard 1993) and *Pelicans, Cormorants and their relatives* (Nelson 2005). Readers

wishing to discover more about these fascinating birds are urged to consult these comprehensive volumes.

The Great Cormorant is near cosmopolitan in its range, which is 'wider than any other Pelecaniform: from Iceland to New Zealand through Eurasia and Malaysia, tolerating astonishing range of topography, climate, and habitat from tropical to arctic, sea level to 3,400 m, coast to continental interior, all continents except South America' (Nelson 2005: 413). Despite this vast geographical range and tolerance for diverse aquatic and wetland habitats, the Great Cormorant's numbers globally are 'fairly modest and far exceeded by even single colonies of several other pelecaniforms' (Nelson 2005: 413).

Great Cormorants have been hunted for their flesh for millennia and are still taken as food in Norway for instance where some 10,000 birds may be taken per year. Elsewhere the species' fishing skills have been exploited on Dojran lake in Macedonia where fisherman use wing-clipped Cormorants and other fish-eating birds to drive fishes into specially constructed traps (Gabriel *et al.* 2005). More commonly, especially in China and Japan, Cormorants can be domesticated and trained to catch fish for human consumption (see Nelson 2005: 98). However, the Cormorant's fish-catching abilities are usually viewed in a more negative light. For years, probably for centuries, there has been discussion about Cormorants as fish-eating predators and potential competitors with man for food in both marine and freshwater environments.

In the first half of the 20th Century, the number of Cormorants in Europe was greatly reduced but, primarily due to conservation legislation and resulting actions, the population in Europe has grown substantially (for example, see van Eerden *et al.* 2003). However, this 'conservation success' for some has caused great concern to others. Representatives in sectors such as fish farming, sports fishing and commercial fisheries have all voiced their displeasure and stressed the harmful effect of Cormorant predation on their business and way of life. This conflict of interests between Cormorants and fisheries was the subject of an extensive synthesis at the pan-European level (Carss 2003, Carss & Marzano 2005) which ultimately formed the foundations for the **INTERCAFE COST** Action.

General description of the Great Cormorant

Three species of Cormorant commonly occur in Europe, the Great Cormorant, Pygmy Cormorant (*P. pygmeus*) and the Shag (*P. aristotelis*), the last two species being described further in Appendix One. There are thought to be six races of Great Cormorant around the world but only two, *Phalacrocorax carbo carbo* (the 'Atlantic' race) and *P. c. sinensis* (the 'Continental' race), occur in Europe. *Carbo* Cormorants tend to be restricted to the Atlantic coasts of Norway, Britain, Ireland and northern France, whilst the *sinensis* race is far more numerous and is distributed across much of the rest of continental Europe and Scandinavia, through Asia east to Japan and south to Sri Lanka.

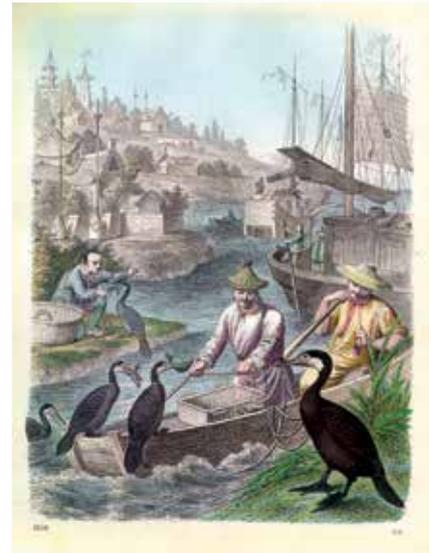


Figure 2.1 Catching fish with Cormorants in eastern Asia (from Hoffman 1858).



Figure 2.2 Adult Great Cormorant. Photo courtesy of J Trauttmansdorff.

Whilst *carbo* birds tend to be larger than those of the *sinensis* race, there is some overlap (both in size and geographical distribution) and so there is the possibility of confusion in the field (though see section 5.5 for further details). Similarly, in the field it is often difficult to distinguish the sexes despite overall differences in average body size (mass) and in the

shape of the head (see also sections 5.3 and 5.4).

Cormorants are very well adapted to their way of life, catching and feeding on fishes almost exclusively. The species forages in a very wide range of aquatic habitats in both salt and fresh waters, preferring relatively sheltered and shallow coastal areas, lakes, reservoirs, lagoons, floodlands, open water in swamps and other wetlands, deltas, estuaries, salt pans, rivers and canals (Cramp & Simmons 1980).

While swimming, the Cormorant's body often lies deep in the water and the tail is flat on the water surface. The hollow bones of the Cormorant have less air in them than many other birds and so the species has a relatively high specific weight. For diving, Cormorants use their feet as paddles and keep their wings close to the body whilst underwater, steering with the tail feathers. The plumage of the Cormorant is less waterproof than that of other waterfowl and it absorbs water relatively quickly whilst the bird is diving. On one hand this makes diving easier (by increasing the bird's specific weight) but on the other hand it shortens the maximum diving time (exposure) and forces the birds to dry the feathers after diving. This wing-spreading posture is very typical of the species and, as well as helping to dry the plumage, it is also suggested by some to be an aid to the digestion of large, cold fish.

The sharp hooked bill of the Cormorant is an efficient means of catching and holding on to its fish prey. Fish are usually held behind

the gills and are often manipulated on the water surface before being swallowed head-first. Smaller fish may even be swallowed whilst the bird remains underwater. The average length of fish taken lies between 10 and 25 cm but birds can take both shorter and longer individuals, their ultimate size being limited by the gape of the bird. The daily amount of fish taken by an individual Cormorant varies throughout the year, depending on things like the bird's breeding state, whether it is feeding young, or on the time of year — birds may require more food (i.e. energy) during the wintering period. On average (though see section 4.6), most birds probably consume around 500 g of food per day, though the Daily Food Intake can be highly variable, depending on the time of year and the birds' behaviour. For instance, flying one hour probably requires the consumption of about 50 g of fresh fish.

Cormorants are social birds, breeding and roosting in large aggregations and, under certain conditions, foraging in large flocks of up to 2,000 individuals.

Cormorants adapt their foraging behaviour to the food available in the different types of waters and so, in big water bodies (e.g. the IJsselmeer in the Netherlands) with large schools of small fish, they form feeding flocks, whilst on many smaller rivers where individual fish tend to be more widely dispersed, Cormorants tend to hunt individually.

Over the year, Great Cormorants can be observed in suitable habitats across the whole of Europe (and even into Northern Africa during the winter). During spring, most Cormorants breed along European coasts from the Netherlands up to the Scandinavian and Baltic countries, although landlocked countries (or those with little coast) also hold numerous inland colonies (see chapter 7 of van Eerden *et al.* 2012). After rearing their chicks, birds start migrating around the colonies. In autumn, when the water temperatures are dropping, and fishes often move to deeper regions and are not so available to the birds, Cormorants generally start migrating southwards. They disperse very widely during the winter and can be found in all



Figure 2.3 Swimming Cormorant. Photo courtesy of J Trauttmansdorff.

regions where open water bodies with enough food are available (see chapter 8 of van Eerden *et al.* 2012).

Great Cormorants usually breed for the first time when they are two or three years old. The nesting place is occupied by the male who displays there for the attention of a female. Later both birds build the nest together. Here, the female lays 3–4 (occasionally 5) eggs with a laying interval of 1–2 days. Both parents incubate the eggs alternately and after 28–29 days the young hatch in laying sequence. Both adults then feed the nestlings, first a ‘soup’ of pre-digested fish and later whole fish, which the chicks take out of the throat of their parents. After 4–5 weeks the young start to leave the nest and successively explore their surroundings. In total it takes between 50–60 days for the young Cormorants to be able to fly but they continue to be fed by their parents for another 3–4 weeks before becoming fully independent.

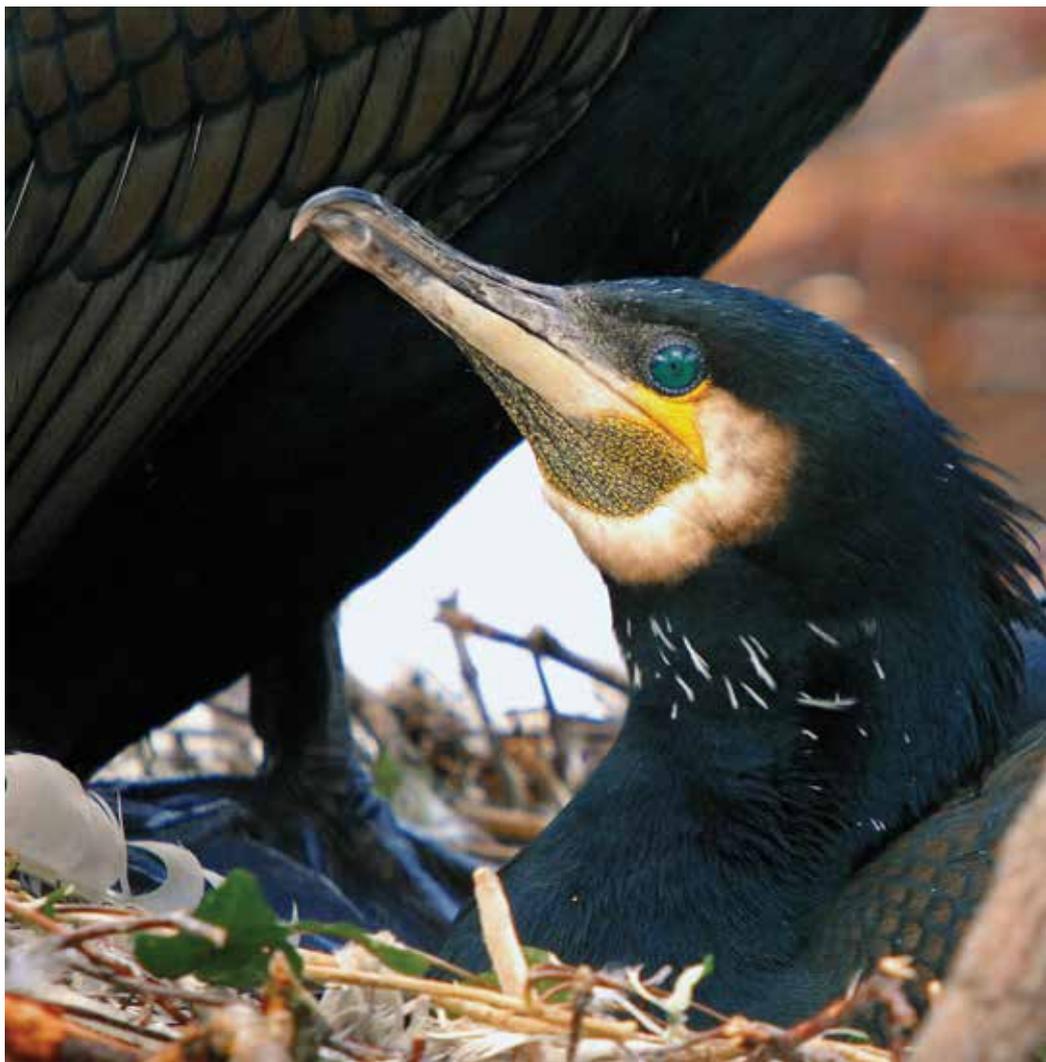


Figure 2.4 Breeding Cormorant. Photo courtesy of J Trauttmansdorff.

2.2 Some important words of warning

This Field Manual includes information on numerous field and laboratory techniques that can be used to conduct research into Cormorants, fishes and the interactions between them. However, many of the techniques require skilled application and some are potentially dangerous and pose very real (i.e. potentially fatal) safety risks. Much of the information, and certainly the sentiment, of this section is taken from Gilbert *et al.* (1998). This Field Manual is *not* a key source of Health and Safety advice, nor is it a Health and Safety handbook and the compilers of this Manual do not

accept responsibility for accidents that occur whilst undertaking any of the work described herein. All fieldworkers should consult local experts with relevant experience before undertaking any fieldwork. More thorough texts on Health and Safety are available from most research institutions and NGOs and must be consulted wherever necessary. Moreover, training from an experienced researcher will often be necessary before any field work is attempted. The following safety reminders are largely common sense suggestions for what may be difficult tasks undertaken in difficult conditions.

All species are to some extent affected by human disturbance (directly or indirectly) and many are particularly vulnerable during the breeding season. Thus, ‘as little disturbance as possible’ is a good general guideline for all fieldwork. In **ALL** circumstances, permission should be obtained before gaining access to private land. Furthermore, for many research activities (bird catching and ringing or many forms of fish sampling for example), official (national or regional) licences are required. Moreover, many of these require some form of intensive training before they are issued.



Advice on these matters will be available from national authorities or established researchers in the relevant field. Before undertaking any fieldwork, no matter how simple it may seem, it is essential for researchers to think carefully about all the potential risks involved, including the task itself, the environment, the weather, the time of day or night, and any other special circumstances. It should also be noted that working in the field alone can significantly increase the level of risk that a researcher is exposed to. Researchers also need to consider and be aware of potentially very serious occupational diseases that they might be exposed to such as Tetanus, Lyme disease (tick-borne) and Leptospirosis (including Weil's disease). Field researchers should consider the most suitable clothing for the habitats and season they are working in and also carry extra clothing if necessary. They should also consider the need for a 'survival bag' and appropriate food and drink supplies, and

carry a map, compass, whistle (for attracting attention in an emergency), waterproof watch, torch (and spare batteries) and, always, a first-aid kit.

Fieldworkers should also always leave details of their planned location with a responsible person, including date and time of departure, means of transport (including vehicle identification details if appropriate), itinerary, any potential hazardous techniques to be used, expected time of leaving the site and returning to base. This responsible person should be told what to do and who to contact in the event of the fieldworker not returning.

This section is just a very brief overview of some of the key Health and Safety issues that should be considered by workers before stepping out into the field. It is not comprehensive nor is it any replacement for any specialist training required or the help and advice of a local experienced expert in the field.

3 COUNTING CORMORANTS

T Bregnballe, D N Carss, S-H Lorentsen, S Newson, J Y Paquet, R Parz-Gollner, S Volponi

This chapter focuses on Cormorant population counts for both summer (i.e. breeding) and winter (i.e. migration, winter roosts) seasons. It also explains differences in the data collected from undertaking ‘day’ versus ‘roost’ counts, gives some definitions of the term ‘numbers’, and presents two examples of how numerical data can be used to calculate ‘Cormorant days’ and breeding success.

3.1 Introduction

Across Europe there is considerable variation in the numbers of Cormorants, their breeding and wintering aggregations, and migration patterns. Ecologically, the population dynamics and migratory and foraging behaviour of the birds is complex. Moreover, Cormorants forage in a wide variety of habitat types, taking a diverse range of prey species.

Cormorants are large birds and are often very conspicuous and relatively easy to spot in the landscape. However, counting them, or more importantly, counting them in an accurate and reliable way — in a way that the numbers produced are biologically meaningful — is far from a simple task.

The techniques used to count Cormorants will depend to a great

extent on why information on bird numbers is being sought in the first place. However, whatever the reasons for counting Cormorants at a particular place and time, consideration has to be given to the bigger picture — of both geographical area and Cormorant behaviour and ecology — if the resulting counts are to have any biological meaning. The term ‘biological meaning’ is important and we will discuss it here.

An observer standing on the bank of a river or a lake or fish pond may see many Cormorants on the water. However, over a relatively short period of time, new birds may arrive and others leave. Over the course of a single day there can often be considerable variation in numbers at any particular site, tending to peak in the early morning and again in the late afternoon. An individual bird’s decision to remain in a particular place could depend on such factors as the amount of food it has eaten, the prevailing weather conditions, the time of day, the tidal cycles (in an estuary for instance), and the level of disturbance from humans or competition and interference from other birds foraging at the same site. A bird’s decision to remain at a particular site may also depend on the site or sites it visited previously and the range

of potential ‘new’ sites to visit. The choice to move to a new site may also be influenced by such things as the bird’s previous experience there, and its distance away — flight is an energetically costly business.

Cormorants are highly mobile birds and in any one area they will certainly move between foraging and resting (loafing) sites, and between these and a communal night roost. As Cormorants are moving about within a given area, a count of individuals at one particular site does not necessarily mean a lot in relation to the actual number of birds in the area. But what do we mean by ‘area’? Generally, it is thought that Cormorants range 5–25 km between roosts and foraging areas each day, although this range could extend to 40–60 km. However, Cormorants can also make wider excursions — perhaps leaving an area for several days and travelling some hundreds of kilometres before returning to their ‘core’ area. On top of these ‘local’ movements, Cormorants also exhibit seasonal migration (see chapter 6 of van Eerden *et al.* 2012). Birds breeding in the north of Europe may move south across the continent during autumn to their wintering quarters in the south. In late winter and early spring they will make the

return journey north, often stopping for short periods of a few days (perhaps more) in a number of regions or countries before arriving once again at their breeding colonies.

Thus, given the complexities of Cormorant numbers on both a daily and an annual basis, the concept of ‘area’ (in terms of how many Cormorants it holds) is a flexible one. It is also very clear that the area associated with any particular Cormorant count should always be defined as accurately as possible, and that the potential errors in such counts be fully understood.

The logistics, labour, and coordination required to count birds over large geographic areas are considerable and should not be underestimated. Similarly, the complexities of Cormorant behaviour and the flexible nature of the ‘area’ being used by individual birds at any particular time of day or season are always on the mind of those Cormorant ecologists or birdwatchers and others who attempt to count the birds. In this section we describe how best to count Cormorants in each of these situations — at breeding colonies, at night roosts and on foraging grounds. Throughout, the aim is to understand the limitations of common methods used to count birds and recommend those methods that produce the most accurate, reliable and repeatable figures.

3.2 Breeding colony counts

Two sub-species or races of the Great Cormorant (*Phalacrocorax carbo*) breed in Europe but at least

three other races of the species are known in north-western, west and south Africa, and Australia, Tasmania and New Zealand (Nelson 2005). The nominate race *P. c. carbo* breeds around the coasts of north-western Europe (Norway, Great Britain and Ireland, and in northern France). Though mainly coastal during the breeding season, this race frequently occurs in freshwaters outside the breeding season. The *carbo* race is almost entirely ground-nesting, including coastal cliffs and rock stacks offshore. The *P. c. sinensis* race breeds from southern Norway and Finland in the north throughout Central and Southern Europe, mostly in brackish and fresh water systems. The *sinensis* race mostly breeds on aerial structures (mostly trees but also shrubs and man-made structures, but also on the ground in reed beds, bare rocks, beaches, on islands or sand dunes). The method used to count nests thus depends partly on whether they are in trees or on the ground.

Definition of a colony

Historically, the definition of a ‘colony’ has varied somewhat among countries, as nests often occur in discrete groups of varying size and can be spread over a considerable area whilst groups of nests may frequently change in size and specific location between breeding seasons. Thus for biological reasons, and in order to improve future possibilities for making comparisons over time and between countries, we recommend use of the following definitions: a colony should be considered separate from another one if it is isolated from other group(s) of nests by at least 2,000 m. Therefore, groups of nests should

be defined as belonging to the same colony if they are located within 2,000 m of the nearest neighbouring group of nests. Similarly, visibly separate groups of nests (but still within 2,000 m of one or more other groups of nests) should be referred to as ‘sub-colonies’. Finally, a single occupied nest is sufficient to be classified as a separate colony if it is located more than 2,000 m from any other nests.

Cormorants breeding on the ground tend to nest in discrete and well-defined groups but the exact location of these groups may shift from year to year. Care must therefore be taken during nest counts in ground nesting colonies to check all potentially suitable sites for the presence of isolated, or newly-established, groups of nests.

Definition of colony size

Cormorant nests can vary from little more than a depression in the ground with little or no additional nest material, to large structures of sticks and debris — often containing 100s or 1,000s of twigs and other material and growing over the years to around 1m wide and 0.5 m high. At the start of the breeding season, potential nesting sites (some with and some without nesting material) are advertised to potential mates by male birds. It is mainly the male that brings nesting material to the nest when building new nests or refurbishing ones used previously. A complete nest may be built from scratch in less than five days.

There has been some variation among and within countries with respect to the precise definition of colony size, mainly because of

different approaches to including (or not including) partially completed nests in nest counts. To standardize counts, we strongly recommend that colony size be defined as the number of apparently occupied nests (often referred to as ‘AON’). An apparently occupied nest is a nest that is in use and sufficiently completed to hold one or more eggs (i.e. nests without eggs or chicks are included if they are presumed to be occupied by a nesting pair).

The number of apparently occupied nests can then be taken as a minimum estimate of the number of breeding pairs within the colony. Whilst this method is probably the most reliable for estimating the total minimum number of pairs of birds breeding at a colony in any one season, it clearly does not represent the possible maximum number of birds associated with the colony as it does not include young birds that prospect for breeding opportunities, or others that might have attempted but failed to find a mate and breed during the season.

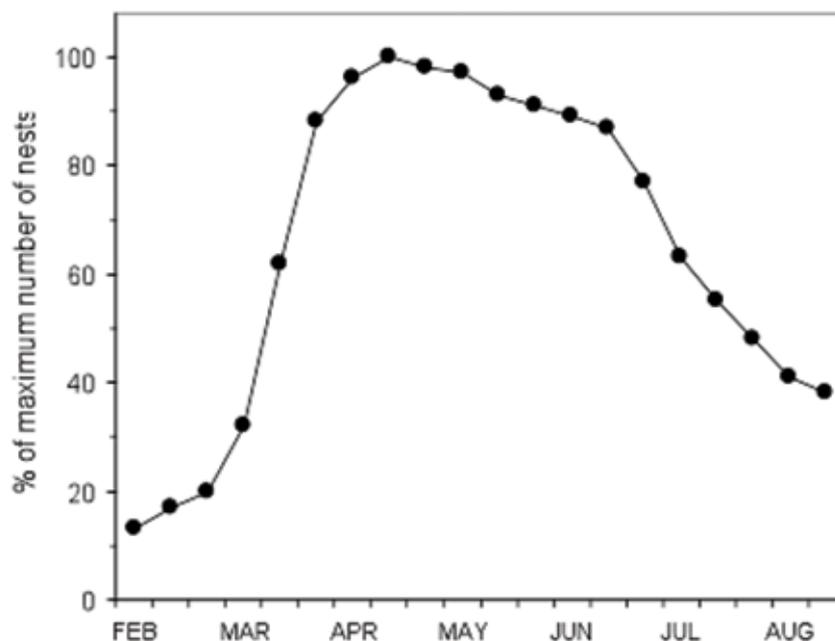


Figure 3.1 Seasonal change in Cormorant nest numbers given as the percentage of the maximum number of nests counted in each 10-day period in a section of the Vorsø colony in 1983.

The final (minimum) breeding count (of pairs of Cormorants) is thus the maximum AON count.

Timing of the count

Clearly, the most accurate count of Cormorant nests (and hence, colony size) should be made when

the maximum number of nests are occupied. If the colony is visited, and nests counted, several times during the same season, the convention is to use the maximum count of AON as the size of the colony in that particular year. However, the ability of the observer

Table 3.1 Best estimate of the timing of maximum nest numbers in Great Cormorant colonies for different countries in Europe.

| Country | Period when maximum nest numbers occurs | Comments |
|------------------------------|-----------------------------------------|------------------------------------------------|
| Norway ¹ | 1 May–15 June | Coastal colonies of <i>P. c. carbo</i> |
| Denmark ² | 25 April–10 May | Coastal as well as inland colonies |
| England ³ | 12 April–17 May | Inland colonies of mixed <i>sinensis/carbo</i> |
| Wales ³ | 10 May–7 June | Coastal colonies of <i>P. c. carbo</i> |
| Italy ⁴ | 15 April–30 May | New colonies settle later |
| Czech Republic ⁵ | 25 April–5 May | South Bohemia |
| The Netherlands ⁶ | March | Inland colonies |
| The Netherlands ⁶ | May | IJsselmeer colonies (1978–2000) |
| The Netherlands ⁶ | April | IJsselmeer colonies (2001–2005) |
| The Netherlands ⁶ | May/beginning of June | Coastal colonies |
| Germany ⁷ | First half of May | |

¹ Røv, N, and Lorentsen, S unpublished; ² Eskildsen, J, Gregersen, J, Sterup, J, and Bregnballe, T. Unpublished; ³ Newson, S. unpublished; ⁴ Volponi, S. unpublished; ⁵ Martincová, R, and Musil, P. unpublished; ⁶ van Rijn, S, and van Eerden, M R; ⁷ Knief, W. unpublished.

to make a count at the time when nest numbers are at their maximum will often be constrained by several factors. An observer rarely knows exactly when during the season nest numbers can be expected to be at their maximum. In planning the timing of a nest count, the observer also needs to take into account the fact that (1) the number of nests tends to reach a maximum later in the season in relatively newly-founded colonies than in older, long-established ones, and (2) that the visibility of nests in trees declines during the season as leaves emerge and hide nests from view.

Observers may also be forced to count at a sub-optimal time for numerous reasons, including poor weather conditions and/or visibility at the time of the planned count. Furthermore, in cases where the counting of nests can be expected to lead parents to temporally abandon eggs and/or chicks, it is very

important not to count when it is raining or during very cold or very warm weather to avoid chilling or heat stress to either eggs or chicks.

The timing of maximum nest numbers within a colony may vary between years and from colony to colony. Several publications present information on the variation in timing of egg-laying and hatching, events which are both correlated with the timing of nest building (e.g. Newson *et al.* 2005, Kopciwicz *et al.* 2003). However, few studies have presented information on the seasonal variation in nest numbers within a single colony. An example of such seasonal variation in nest numbers is shown here for an area within the Vorskø colony in Denmark (Figure 3.1). Clearly, the maximum number of apparently occupied nests ($N = 315$) was counted on the 8th visit (during April), a count on the 4th visit (during March) would have underestimated this total by around

70%, whilst one made in June would have underestimated it by about 10% and one in July by as much as 50%.

In Table 3.1 we give a best estimate for the timing of maximum nest numbers in different countries, based on the experience of those involved in monitoring Cormorant colonies. These periods can thus be taken into account when planning the timing of counts in each country. The timing of maximum nest numbers in Europe is partly related to location of the colony in relation to a North-South and East-West gradient (see sketch in Figure 3.2), but it also varies locally, partly depending on seasonal variation in food availability. For example, in Great Britain Cormorants breeding on the coast initiated breeding several weeks later than those breeding in inland colonies (Newson *et al.* 2005).

To sum up, although there is a broad pattern in geographical

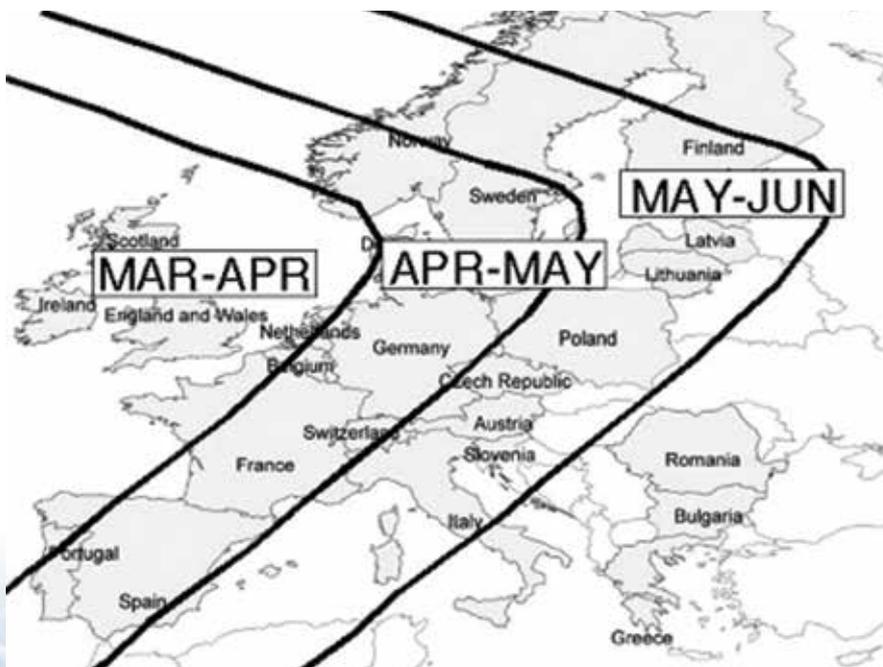


Figure 3.2 Sketch of the general time shift in breeding Cormorants from north to south and west to east across Europe.



Figure 3.3 Ground nesting colony Denmark. Photo courtesy of T Bregnballe.

variation in timing of breeding (as indicated in the table), there is also considerable annual variation and variation within regions. Ideally, counts of nests in a colony should be carried out when the maximum number of nests are occupied. However, this is sometimes not possible because observers very often only have one chance to visit a colony during the breeding season. Unfortunately, there is no easy way to 'correct' or 'adjust' nest counts to account for the fact that they were not made at the time of maximum nest numbers. For these reasons, many counts are often an underestimate of maximum AON.

Finally, the number of pairs attempting to breed in a colony will in most cases be higher than the number of nests counted even at the time when nest numbers reach their maximum (e.g. Harris & Forbes 1987, Walsh *et al.* 1995). For example, a nest built by a pair that gave up early in the season may be taken over later by a new pair, and nests may disappear before (and new nests may be built after) the maximum in nest numbers is reached in the colony - as has been shown for Shags *Phalacrocorax aristotelis* (Harris & Forbes 1987).

3.2.1 Nest counts in ground-nesting colonies

Counts from the ground

Care should be taken to minimise disturbance. This must be given high priority in order to reduce the exposure of eggs and nestlings to both weather and predators. We therefore recommend that entering the colony is avoided if possible. Instead, the observer should find a

suitable vantage point (or several if necessary) and count the nests from there. Registering nest content is not essential for counting nests, but if possible a general assessment of the stage of the breeding cycle should be given (i.e. record approximate proportion of nests with eggs, <1 week-old chicks etc.). If repeated counts are performed, the highest number recorded should be used as the total number of AON's for the colony. In some colonies it may not be possible to see all parts from the vantage point(s) selected. Keep a note and a map of the parts of the colony that are not visible and try to estimate (minimum-maximum) the number of AON's likely to be hidden, based on numbers in the visible sectors of the colony. When reporting the results of the count of nests, make clear how many were counted directly and how many are of unknown reliability.

Entering the colony may be the only option available in some ground-nesting sites because vantage points are unavailable. In this case, sticks can be placed in the ground within the colony or spray paint used on selected nests to keep track of the parts of the colony where nests have been counted. The duration of disturbance can be reduced by having two or three persons carry out the count together. The extent of disturbance will, in some areas, also be lower if the count is carried out during the night. This is frequently done in Norway where summer nights are long and darkness is not a problem (N. Røv pers. comm.). Counting nests at night in northern latitudes has the advantage that adults tend to remain on their nest for longer and that gull predation is lower than during daytime disturbance.



Figure 3.4 Counting of ground-nesting colony. Photo courtesy of T Bregnballe.

Obviously, counts during dark nights should be avoided.

In cases where observers walk through the colony counting nests and recording nest contents (eggs and chicks), we recommend that information is dictated into a tape recorder. This enables the observer to keep a better track of which nests have (and have not) been counted and it minimises the duration of disturbance. When recording nest contents, we recommend recording for each nest the number of eggs, number of chicks, and estimated age of the oldest chick in the brood (give age in estimated days since hatching, see section 5.6 on biometrics for age determination).

Cormorants breeding on the ground tend to nest in discrete and well-defined groups but the exact location of these groups may shift from year to year. Care must therefore be taken to check all potentially suitable sites for the presence of isolated, or newly-established, groups of nests

Using aerial photographs

The best method, and in some areas the only one suitable for

counting ground-nesting colonies, is to photograph the colony from the air. Subsequently, large prints of the photos should be made, or slides projected onto a large sheet of paper or the wall. Nests can thus be easily counted by marking them off. Be aware of double-counting sites if several photos from the same colony are used. It is recommended that several observers count nests from the same photo and that the mean of these counts is used as the size of the colony.

3.2.2 Nest counts in tree-nesting colonies

In planning the timing of a count, it should be remembered that the visibility of nests usually declines quite rapidly (within a few days) as buds burst and leaves grow on trees. Before counts commence, it should be determined whether some sectors of the colony can be counted from outside, thereby minimising disturbance. However, it is usually necessary to walk

through the entire colony to count all nests and keep track of those that have (and have not) been counted. It is helpful to make maps of the colony and to use features in the landscape (e.g. certain individual trees) to keep track of the sections of the colony that have been counted.

Nest counting in tree-nesting colonies will often cause extensive disturbance to the colony. Be aware that incubating Cormorants suddenly detecting a person in the colony can flush from the nest immediately causing one or more eggs to fall out of the nest. A nest count in a tree-nesting colony will frequently lead to the exposure of eggs and small nestlings to predation from crows and magpies. The loss of eggs and chicks can be minimised by moving around in the colony in a way that minimises the number of nests disturbed within any given time period. Finally, be aware that Cormorants sometimes breed in mixed colonies with other species like herons and that the

nests of these other species may be mistaken for those of Cormorants.

3.3 Roost counts

Standard waterbird counts — well established in the European birdwatching community to collect bird-census-data in wetland habitats — are normally conducted during the day time. However, this counting methodology is not appropriate when assessing the total numbers of Great Cormorants in a specific region during the winter or the migration period. This is because Cormorants frequently move between foraging and loafing sites during their daily activities and there is a strong risk of either missing birds or double-counting individuals. Cormorants also tend to use a variety of water habitats including small rivers or lakes that are generally not taken into account during standard waterbird counts. As a result, it has been calculated that counting Cormorants using the standard waterbird count technique can underestimate regional numbers of birds by at least 30%, and that this counting error varies greatly according to specific local situations (Newson *et al.* 2005, Worden *et al.* 2004).

We therefore strongly recommend that workers seeking an accurate count of Cormorants take advantage of the communal roosting habit of the species, which allows accurate counting in most of European wintering and migration situations. In practice, this means that Cormorant counts must be made by ‘controlling’ (i.e. counting the numbers of birds at) roost sites in a coordinated and simultaneous way in the late afternoon before dusk. Text Box 3.1 gives the



Figure 3.5 Tree colony in Lepelaarplassen in the IJsselmeer area, Netherlands.

Photo courtesy of Mervyn Roos.

- Where to count: count Cormorants on night-roosts.
- When to count: simultaneous evening counts (late afternoon before dusk).
- Data collection: use standardized protocols to take records.
- Frequency of counts: once a month at least during main migration period (depending on field workers' capacity, geographical area with respect to phenology, and large-scale movements).
- Coordination of counts: regional, national, international levels.

Text Box 3.1 Recommended methods for counting migrating Cormorants at inland sites.

recommended methods for counting migrating Cormorants at inland sites.

Communal night roosts

At the end of the day during the non-breeding season, and especially in the winter, all Cormorants from a given area aggregate at a communal night roost - a traditional site used as a resting site night after night and year after year. These roosts are always located adjacent to a significant area of water in relatively quiet places (preferably islands or undisturbed shorelines). Most roosts are located on riverside trees (dead or alive, deciduous or coniferous) but roosts can also be located on sand or gravel banks, artificial structures, small pools, rocks in the water, and even on cliffs. Choice of roost site depends on the nature of the waterbody (e.g. marine coastline, river, lake, man-made inland waters, presence

of islands) and the geographic latitude. However, regardless of its location, any roost where birds congregate and rest is easy to detect due to the white colour of the guano that is visible even in late autumn when most trees are still covered with leaves.

'Day' and 'night' roosts

Cormorants gather at roosts both during the day and at night. After foraging, Cormorants tend to form diurnal roosts ('day roosts'), close to their feeding areas. Generally, day roosts contain only a few dozen birds but some may be used by hundreds of individuals. Counts from day roosts should not be used to estimate regional Cormorant numbers because birds may switch between locations or use several places during the day for resting and drying their plumage after a foraging bout. In order to distinguish a diurnal roost from a night roost it is necessary to wait until nightfall to see whether Cormorants leave a particular roost at dusk and move to a different one to spend the night. Night roosts can also be occupied by a variable number of birds throughout daylight, indeed most 'traditional' night roosts (used year after year) are also known to serve as day roosts.

At the end of the day however, every Cormorant will congregate at a night roost that can hold anything from a few birds to around a thousand individuals. Very rarely, such night roosts may hold several thousand individuals. As flying is energetically very costly for wintering Cormorants, the distances between night roosts and foraging sites are generally only a few kilometres, though the distance



Figure 3.6 Roost site with wintering Cormorants (in January), mixed flock with juvenile and adult birds.

Photo courtesy of J Trauttmansdorff.

can sometimes be up to 30–40 km. Consequently, in winter, any given night roost generally holds most, if not all, of the Cormorants that have spent the preceding day within a 30 km radius. Cormorant numbers at night roosts are lowest in the early morning but increase gradually during the day to a nighttime maximum, as birds return from foraging trips.

3.3.1 Counting methods: where, when and how?

Where to count

Depending on the area to be covered, winter Cormorant counts need to be coordinated by a regional, national, or international coordinator responsible for collating individual roost counts from various locations to produce



regional, national, or international totals. Most large-scale counts (e.g. regional, national, international) require a dedicated network of teams of field workers in order to ensure full coverage. For example, the first coordinated winter count of Cormorants across Europe (January 2003) required the efforts of over 3,000 individual observers counting birds at night roosts.

Before starting to count, an inventory — including the geographical coordinates — of all the known night roosting sites in the area to be counted should be prepared. As well as detailing the scale of the task, this inventory will indicate the number of field workers required to undertake the counts. For a coordinated winter count, at least one person should be given responsibility for each known roost. Ideally, this person should be familiar with his or her particular roost and know the best

vantage points from which to count birds and details of the Cormorant's behaviour in relation to the roost site.

If the traditional roosting sites are not known by local observers in the area to be counted, then some preparatory field work is needed to locate them before any scheduled large-scale count. Interrogating the local network of observers, through internet forums or regional bird watching journals may help.

When to count

Cormorant night roost counts should be coordinated in time within a certain area. This means that all counts have to be carried out on the same day simultaneously by all observers. This is not a trivial task and requires a lot of preparatory work. To ensure simultaneous counts on a national level, a list of specific counting dates should be agreed amongst the counting team involved well before the migration period starts, and several months before count(s) are expected to take place. In order to produce population numbers from a national census, counts should cover the whole known migration period relevant for the specific country. Thus, when winter roost counts are undertaken at a national (or regional) level, observers need to take into account the stage of migration in that particular area or country.

In order to keep track of the ongoing migration of Cormorants across Europe (from the breeding grounds in the north to the southern wintering grounds), national counts should be scheduled at least once a month (and ideally every second weekend) during the migration period. In this way, a picture of the

temporal development of wintering numbers can be produced (i.e. numbers increasing to a mid-winter peak before declining as birds begin to return to the breeding grounds) and a maximum mid-winter estimate of Cormorant numbers can be derived from the series of counts undertaken.

However, in most European countries, only one officially agreed counting date is used for a general winter count (e.g. that for the International Waterfowl Census). This is because of the logistical difficulties of having many people in the field counting simultaneously several times during the winter months. Traditionally, the agreed date for a mid-winter census on a large geographic scale occurs around mid-January (on the Sunday closest to 15th of January) when most birds moving over the European continent would be expected to have arrived in their wintering quarters.

The considerable coordination (and field) skills of such simultaneous (i.e. 'agreed date') counts can not be underestimated. The logistical and practical issues to be considered are immense. Cormorant flocks can frequently shift between adjacent night roosts locally, or over a wider area, and so simultaneous counts on the same date require detailed national coordination. Similarly, close international coordination and collaboration is crucial between neighbouring countries as they often share roost sites or roosting locations along national borders (often along river courses).

On a pan-European level, the actual date of the counts in relation to the

timing of the wintering migration is actually less critical. This is based on the assumption that, regardless of the phase of migration in any particular region at the time of the simultaneous count, 'all' birds will be recorded because counts are undertaken simultaneously on a large-scale across the whole continent at the same time (day or weekend).

How to count

Field workers normally use binoculars or a telescope to count Cormorants. Observers should work from a sheltered position that offers a good view of the roost but does not go closer than the bird's 'reaction' distance (i.e. no closer than around 200 m, but reaction distance can be shorter in places where Cormorants are not subject to shooting and so are more tolerant of human presence) so that the birds can enter or leave the roost without disturbance. The more birds that are present at a roost, the more difficult it becomes to collect and record additional information on a small scale (e.g. position of individual birds, age ratios). At large roosts, flight movements might happen so fast, and in such big waves, that here observers need to concentrate all their efforts on just counting the numbers of birds with perhaps only little time left to take short notes on the flock size of arriving birds and their direction(s) of flight.

In general, counting birds moving in big flocks, requires considerable training and practice which can only come through field experience and dedication. Such counts may be made easier through the use of counting teams where one observer watches the birds

through binoculars or a telescope and a second records the running commentary from his/her colleague on bird numbers, flight direction, flock-size, age composition and so on.

Undertaking an evening count

Ideally, birds using communal night roosts should be counted at the end of the afternoon/early evening. The observer should be in place around two hours before dusk, but this period can be shorter if the roost is small (up to 300 birds) and/or the observer is familiar with the birds' behaviour at the specific location. However, it is absolutely crucial that the observer continues to count until it is completely dark and that the time he or she leaves the counting spot is recorded. Cormorants rarely enter roosts in the few minutes before complete darkness but if neighbouring roosts are disturbed, or birds have experience of harassment actions, flocks of disturbed birds can be expected to arrive at roosts even after sunset when it is getting very dark. For these reasons, it is important to proceed with counts in the following recommended way:

- On arriving at the counting spot (write down starting time), start with a preliminary overview counting every bird already present in the roost (and, if possible, estimate the age-composition, see age determination paragraph at the end of 3.3.2 below and also section 5.2).
- Take records regularly every 10–15 minutes, write records down on a protocol list chronologically (see Appendix Two for example).

- During the counting period, record every bird entering the roost, paying particular attention to large flocks. Record both the time of arrival at the roost and flight direction of the birds if at all possible. This information will help regional coordinators identify any Cormorants shifting between simultaneously-counted neighbouring roosts.
- Just before complete darkness, make a final count of all the birds present. Remember to stay until complete darkness and record the time the count is completed. Write down the time when you leave the observation point.

Undertaking a morning count

Depending on the locality and the size of the roost, morning counts can also produce reliable figures for the number of Cormorants using them. Morning counts are generally less accurate than those made in the evening and this should be taken into account when interpreting particular counts.

Nevertheless, morning counts can provide accurate information on the numbers of Cormorants at specific roosts under certain circumstances. For instance, where roosts are relatively small and morning and evening counts have been systematically compared through a series of repeated counts by the same observer. In these cases, the observer(s) should be in position well before the first light of the day (i.e. no later than 30 minutes before sunrise), as some individual birds invariably leave the roost before the mass departure of roosting Cormorants to their foraging grounds. Mass departure from the roost usually occurs when it is still

too dark to accurately count the birds, although in some areas some roosting birds tend to wait until the rising sun warms them before leaving.

Sub-optimal counting methods

Under special circumstances, standard roost counts as described above may not be possible. If this is the case, as a last resort, workers may consider one of the following considerably less accurate methods.

If the roost is not visible from any good vantage point, or is on private property or some other inaccessible place, it might be possible to undertake a departure count. From whatever vantage point available, the observer counts birds during their mass departure from the roost. This relies on the fact that the observer has good knowledge of the local departure flyways. If several major departure flyways are used, there may be a need for several observers. Counting a roost of birds using a flyway to/from the roost should only be used in the morning at the moment of 'mass departure'. Arrival of Cormorants at the roost site can generally occur throughout the day and some birds may even stay at the roost the whole day long, except for a short moment after the mass departure.

If vegetation or other obstacles hide roosting birds, several observers (certainly more than one) may consider undertaking a disturbance count. In this case, one or more people disturb the birds by approaching the roost whilst an observer attempts to count the flying Cormorants. As this method

employs deliberate disturbance of the birds its use must be kept to a minimum.

If either of these types of count is used, this fact must be recorded, and observers must be aware that in general they will get less accurate results from these methods.

Counts at coastal areas, aerial surveys

The counting methods described previously are generally most appropriate for inland roost sites, accessible to observers on foot and have been well tried and tested in many locations. However, it is considerably more difficult to count Cormorant roosts along marine shorelines or on islands, where boats are usually needed to carry observers to 'control' (i.e. count birds at) roosts.

The aerial survey is a frequently used method for estimating waterbird flocks in general, as well as for counting breeding populations (Laursen *et al.* 2008, Pihl & Frikke 1992). To date, only a few European countries (e.g. Finland, Denmark) have used this method to count Cormorants at their roosts during the winter months. As described previously, aerial surveys are much more commonly used to control breeding status, the development of breeding sites or to detect the establishment of new colonies across large areas or ones that are difficult to access.

3.3.2 Data collection, counting protocols (forms)

All data records should be made on specific counting forms (usually following standard protocols),

provided by national or regional coordinators (see Appendix Two for national examples). Many countries have standard national forms for collecting waterfowl data and these can be used, or adapted, for the specific needs of Cormorant roost site counts. If such counts are to be carried out across Europe, guidelines and counting forms should be translated into national languages. As an example of an international count, the standard form for the 2003 pan-European winter roost count is shown in Appendix Two.

What to record?

Most counting forms require observers to make records by using either (a) tick-boxes to choose between various factors (e.g. type of roost, climatic conditions during the count, estimate of the accuracy

- Country, name of département, or province
- Name of observer (at specific location)
- Date of counting
- Precise point in time of single observation and/or time period (duration) of longer observation
- Name of waterbody and roost location (e.g. 100 m upstream of village X on River Y)
- Geographical coordinates, or indication of the roost location on a map
- Total number of Cormorants present at the end of the day (= number of birds staying at that specific roost site overnight)

Text Box 3.2 The absolute minimum information needed when counting Cormorants at night roosts must include the following details.

Table 3.2 Additional data collection (see also Appendix Two for examples of national counting forms).

| Details about ... | Free text and/or tick boxes to record ... |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environment | <ul style="list-style-type: none"> ▪ Type of water body: e.g. river, lake, sea, impoundment area ▪ Location of roost: e.g. island, river bank ▪ Type of roost: e.g. tree, ground, artificial structure, poles, cliffs |
| Counting Conditions | <ul style="list-style-type: none"> ▪ Local climatic conditions: e.g. wind, rain, snowfall, ice cover, fog, visibility ▪ Accuracy of counting /data record: e.g. 100%, 75%, 50%, <50% ▪ Additional comments: instances of disturbance, traffic, hunting |
| Bird Details | <ul style="list-style-type: none"> ▪ Flock size ▪ Arrival time of single birds or flocks (e.g. 1 x 10, 2 x 40....) ▪ Flight directions ▪ Activity of birds: e.g. '16.20h flock of 20 birds, flying upstream/coming from west etc., all birds land in water, swimming and diving; etc.16.30h–20 birds perch on trees...' ▪ Presence of ringed birds (metal and/or color rings) ▪ Age ratio: number of individuals in the flock or estimated percentage |

of counting), or (b) to write specific comments in a series of separate boxes. Text Box 3.2 shows the absolute minimum information needed when counting Cormorants at night roosts.

Additional information

Additional notes about environmental parameters and Cormorants can be recorded during the roost count survey to give a more detailed description of roost 'quality' (e.g. type and position of trees used, general accessibility for humans, nearby roads or waterways being used by whom, frequency and kind of disturbances), flock composition (e.g. age composition) or Cormorant behaviour (e.g. circling, diving, resting on the water/on the ground, showing alert behaviour, comfort behaviour, sleeping = head under wings etc.) under the specific local conditions. In combination these details can be useful in helping to identify the requirements of roosting Cormorants, which may contribute towards a better understanding as to how range expansion is likely to proceed under given environmental conditions.

In practice, the collection of this kind of information (see Table 3.2) should be standardized in some way (e.g. make use of tick boxes in reporting forms) to guarantee that

counters use the same definitions. Frequent counts and records that distinguish between adult and juvenile birds can give valuable information on the 'quality' of a



Figure 3.7 Immature Cormorant (above, J Trauttmansdorff) and adult birds (right, T Bregnballe).



roost as well as on the turnover of migrating flocks (i.e. how long Cormorants stay at particular sites).

Age determination — important note: only completely ‘black’ birds (i.e. black plumage on their front/ventral ‘breast’ side as well as the back) should be recorded as ‘adult’ birds; juvenile or immature birds are pale on their ventral side (completely or partly white, showing various white-black spotted patterns) and are browner on their back. From early January onwards, identification of adult birds is made easier by the presence of white patches on the thighs and sides of the head. However, in many cases (for instance when birds are facing away from

the observer and their breast colouration can not be seen), it can be difficult to distinguish between adult and juvenile birds. Under these circumstances, such birds should be recorded as being of ‘undetermined’ age class (for further details see chapter 5).

3.3.3 Data aggregation and synthesis

In the long run, the opportunity for data aggregation of wintering Cormorant numbers collected on different spatial levels should be the ultimate goal of observers. It is evident that climatic conditions, on various geographic levels, are the driving force influencing the migration of Cormorants over the European continent. The successful survival of birds depends on quick reactions and flexible behaviour on a daily basis in relation to changing environmental conditions, especially during severe winter situations. So the crucial point — to achieve and combine/aggregate Cormorant numbers on a large geographic scale — is the harmonization of a national/international counting date and the use of methods for simultaneous data collection (as a response to the high mobility of Cormorants).

Data collection on a national level

National coordinators (at the country level) are key players in organisation and information transfer. They should be responsible for the distribution of, as well as the collection of, counting forms to/from observers. Regional coordinators should be involved in the often lengthy process of assisting to build-up

and advise the counting teams organized locally. People counting in the field should use forms to compile their counting results either directly into a computer or should fill out the form by hand and send results back to their national coordinator for processing. The collection of forms, summing-up and analysis

Maximum numbers are generally used and reported when dealing, for example, with breeding pairs or the maximum number of mid-winter migrants observed (per month or any other defined time period) in a defined area.

In some cases, perhaps when only a single (or opportunistic) count has been made at a particular place/time, it is impossible to know how representative this count is with respect to phenology. In such cases, the count should be reported as a time- and site-specific **single record**.

Mean numbers are often regularly reported too. In practice the term ‘mean’ or ‘average number’ is used most commonly in relation to Cormorant numbers. The ‘mean number’ of birds can be calculated from regular counts carried out in a standardized way. Numbers presented thus should give the best possible estimate of birds present in any spatially-defined area (e.g. site, region or on the national level) within a given time period.

Text Box 3.3 Conventions and definitions.



When discussing ‘Cormorant numbers’ with respect to wintering birds, a number of associated specific pieces of information should also be given in order to make the numbers meaningful. These are (i) the reference area under consideration, (ii) the relevant time period of data collection, (iii) the frequency of counts (i.e. a single or multiple count), and (iv) the counting method used (i.e. a day or roost count?). So, for example, when talking about Cormorant numbers in ‘Europe’, the names of the relevant Member States, the time period under discussion, and the time of year (e.g. breeding or mid-winter) should be indicated.

When considering Cormorant numbers on a wider geographical-scale, a single figure or count result obtained during one census done in mid-winter (e.g. mid-January) should not be used to calculate the mean number of birds present over a whole winter-migration period (i.e. over several months) within any specified area. This is because, in any given area, numbers fluctuate throughout the year, in relation to the annual cycle or in response to temporary climatic conditions.

Text Box 3.4 Area under consideration and the frequency of counts.

of count results on a country level should be the responsibility of the national coordinators.

Data collection on a European level

Much more effort and organisational work is needed to undertake a

pan-European wide Cormorant roost site count. To do this, one can take advantage of, and gain support through, one of several existing international waterbird census networks (e.g. Wetlands International). Named European coordinators must be identified and they are responsible for an allocated list of countries from which they have to find (and keep in close contact with) national coordinators. Final counting results on a national level, together with a map indicating the distribution of the roost site locations should be addressed to European coordinators, who can ultimately produce a European synthesis.

3.4 How to use numbers?

‘How many Cormorants do you have?’ is certainly the most frequently asked question in the ongoing public debate over potential ‘impact’ of Cormorants at fisheries. It seems to be a simple question but in practice needs to be more specific before a ‘correct’ answer or ‘best estimate’ can be given. For example, which time of year is being considered? What geographical area do the numbers refer to? Are we considering breeding or wintering birds? Do the numbers available refer to the numbers of individuals or to breeding pairs? Are counts available for specific races?

Depending on (1) the goal of the research, (2) the counting effort, and (3) the protocols for data collection, both the ‘quality’ of the data as well as its interpretation can differ in relation to a variety of questions. The following three Text Boxes (3.3, 3.4 and 3.5) intend to give brief overviews of some of the frequently used conventions

and definitions used by researchers dealing with Cormorant numbers.

3.4.1 Counting Cormorants on their foraging grounds and calculating ‘Cormorant days’

This type of data will be of interest for assessing Cormorant numbers using any kind of spatially-defined unit, particularly for property-related issues and fishery

Generally, two distinct methods can be used to collect data on Cormorant numbers at very specific sites. Both address slightly different issues or address different questions in relation to different spatial scales.

Day-counts provide data on the bird numbers and their activity pattern (e.g. in feeding areas). There are two possible methods: (1) the observer stays in one location and monitors the activity of birds over a given time period, and (2) the observer moves around ‘controlling’ (i.e. counting and recording birds) in a specific area, a linear transect, or a defined number of locations, in a standardised way.

Roost-counts provide data on the number of birds present or aggregating from a defined area (activity range). This is the preferable method for use during the migration period, and it also describes the phenology of birds on a wider scale.

Text Box 3.5 Basic methodology — ‘day’ versus ‘roost’ counts.

management discussions on the ‘impact’ of feeding Cormorants on fish stocks.

Most people come into contact with Cormorants when the birds are seen at foraging sites. As foraging sites are the places where feeding Cormorants frequently come into conflict with commercial and/or recreational fisheries interests, this is the starting point for our discussion on counting Cormorants. At a small site, counting is relatively straightforward, if an observer finds a good vantage point overlooking the whole site.

The waterbody should be scanned systematically and a cumulative count made. At any time, some birds will be arriving at the site and some leaving, whilst others will be diving underwater and excluded from counts. Therefore it is necessary to undertake several systematic counts of the water and take the average number, the maximum, or the modal (i.e. the most frequently counted total) count. With care, the most commonly counted total will be the same as the maximum count — but whatever this ‘final’ count is, care should be taken to note how it was derived.

As waterbodies increase in size, it becomes more difficult for a single observer to make complete, accurate counts. In these cases, a single observer (or several) could attempt to count all birds from different vantage points and amalgamate their counts on a final total. However, care must be taken that counts are synchronised to reduce the chances of birds moving between the observation ranges of the observer(s) and being counted more

than once. To this end it is always worthwhile to record additional features while counting — for instance, the numbers (and flock size) and directions of birds moving within the site, and the locations of known roost or resting (loafing) sites — in order to accommodate these in the final ‘best estimate’ of bird numbers.

Even such basic counts can be time consuming and may take several hours, a factor that must be considered when planning counts. It is also necessary to consider at which time of day counts should be undertaken. In general, maximum counts at the same site will vary between morning, mid-day and afternoon periods and this variation may be unpredictable. Maximum numbers can occur during a different time period on different days or even during the same day. For instance, a study at Loch Leven in Scotland (where Cormorants were counted three times a day for 106 days) showed that some counts at one time of day were up to 40% higher than other counts made at different times on the same day (Wright 2003: 347).

Prior ecological knowledge of how the birds use a specific site may allow an observer to choose to count birds at the time of day when their numbers are greatest. However, this is not always the case. The timing of counts will, of course, be constrained by other factors affecting the time period available for an observer to undertake them. Nevertheless, the most important requirement is that multiple counts undertaken over a specified time period at a specific site are undertaken at the same time of day each time. This will at least

ensure that counts are standardised and comparable (even if they do not give the actual ‘total’ number of birds involved).

Intuitively, the logical step after an accurate Cormorant count is obtained (particularly from a fisheries perspective) is to convert this count to some measure (or index) of Cormorant use of the site. At its simplest, this could be a simple calculation of the number of Cormorants counted and the number of days they visit (and presumably feed) at a site. This ‘predation pressure’ is sometimes calculated as:

Number of Cormorants x days of presence at a site

There are two possible ways of calculating this, as follows:

1. By considering the number of birds present on the count day as a constant and then multiplying it for the number of days elapsed until the following count, or
2. By linear interpolation of two consecutive counts

$$\frac{(n1 + n2)}{2} \times d$$

where n1 and n2 are the number of birds counted at time 1 and 2, and d is the number of days that have elapsed between the two consecutive counts (Im & Hafner 1984, 1985). Essentially, this just means that for days between successive counts, it is assumed that the average number of birds (from the 2 counts) were present on the days when counts were not made.

Example A

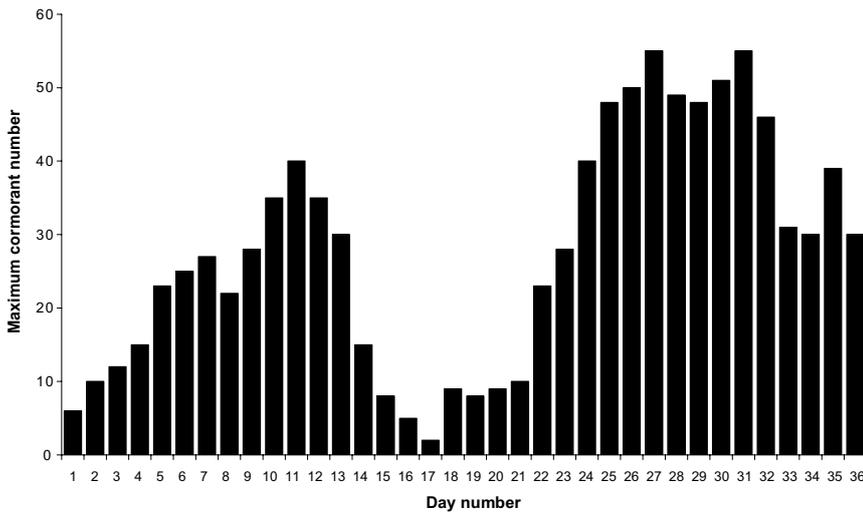


Figure 3.8 Hypothetical daily Cormorant counts (maximum number observed) at a foraging site. Birds were counted by a trained observer at a standard time of day and weather conditions remained similar throughout the 36 day counting period. Example A Table 3.3.

However, each method has its limitations as can be seen in the following hypothetical examples where Cormorant numbers are known on a daily basis for a period of 36 days (Figures 3.8 and 3.9) but we assume, in the first instance, that birds have only been counted once a week, on days 1, 8, 15, 22, 29 and 36.

For this full 36-day count, the actual cumulative number of Cormorant days is 997. Taking the counts obtained on days 1, 8, 15, etc., the maximum numbers of Cormorants recorded were 6, 22, 8, 23, 48 and 30 (on each day) and so the cumulative number of Cormorant-days derived from these 6 counts estimated by methods (1) and (2) are 779 and 857 individuals, respectively (see also 7-day data in Table 3.3).

For this full 36-day count, the actual cumulative number of Cormorant days is 506. Taking the counts obtained on days 1, 8, 15, etc., the

maximum numbers of Cormorants recorded were 7, 11, 56, 11, 7 and 9 (on each day) and so the cumulative number of Cormorant-days derived from these 6 counts estimated by methods (1) and (2) are 653 and 565 individuals, respectively (see also 7-day data in Table 3.3).

Example B

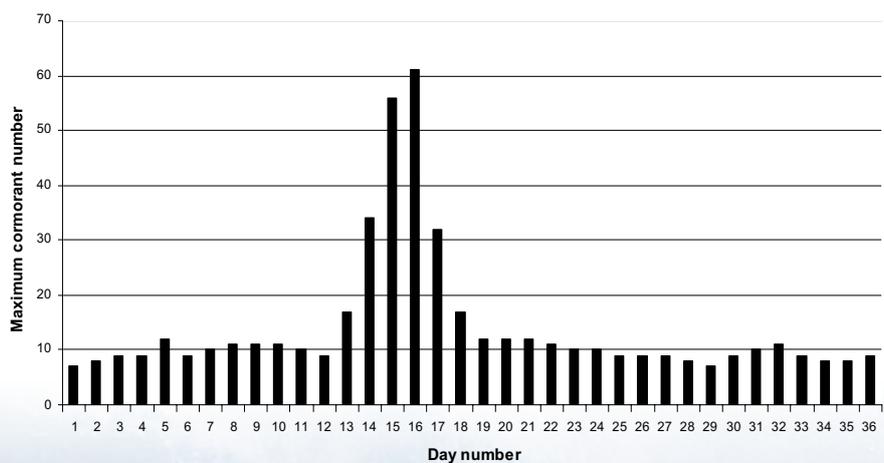


Figure 3.9 Hypothetical daily Cormorant counts (maximum number observed) at a foraging site. Birds were counted by a trained observer at a standard time of day and weather conditions remained similar throughout the 36 day counting period. Example B Table 3.3.

In **Example A**, both methods of estimating Cormorant-days **underestimate** the actual number by varying degrees (22% underestimate for method [1] and 14% underestimate for method [2]). Conversely, in **Example B**, both methods of estimating Cormorant-days **overestimate** the actual number by varying degrees (29% overestimate for method [1] and 12% overestimate for method [2]). In both examples, Cormorant-days estimated by Method (2) which attempts to be more ‘biologically meaningful’ — by taking an average of each subsequent pair of counts — still either underestimates or overestimates the number of Cormorant-days by over 10%. Although such levels of accuracy are common in ecological datasets, it must be remembered that these ‘best estimates’ are just that — best estimates.

As these examples demonstrate, the level of fluctuation (i.e. the difference between the lowest and highest counts in the dataset), as

Table 3.3 Maximum daily Cormorant count every 7 days, actual cumulative Cormorant-days (for daily counts) and estimated cumulative Cormorant-days from 2 different methods. See text for full details.

| Example A | | | | | | |
|----------------------------------------------------------------|---|-----|-----|-----|-----|-----|
| Day number | 1 | 8 | 15 | 22 | 29 | 36 |
| Maximum daily Cormorant count | 6 | 22 | 8 | 23 | 48 | 30 |
| Actual cumulative number of Cormorant days | 6 | 140 | 331 | 397 | 715 | 997 |
| (1) Estimate of cumulative Cormorant days 22% underestimate | 6 | 64 | 204 | 275 | 461 | 779 |
| (2) Estimate of cumulative Cormorant days 14% underestimate | 6 | 112 | 210 | 329 | 593 | 857 |
| Example B | | | | | | |
| Day number | 1 | 8 | 15 | 22 | 29 | 36 |
| Maximum daily Cormorant count | 7 | 11 | 56 | 11 | 7 | 9 |
| Actual cumulative number of Cormorant days | 7 | 75 | 223 | 380 | 452 | 506 |
| (1) Estimate of cumulative Cormorant days 29% overestimate | 7 | 60 | 182 | 529 | 602 | 653 |
| (2) Estimate of cumulative Cormorant days 12% overestimate | 7 | 61 | 262 | 463 | 517 | 565 |

well as the gradient of the curve (i.e. the ‘speed’ at which numbers are increasing or decreasing) can easily influence the result in either direction. Clearly, the most accurate assessment of Cormorant numbers (and hence, of Cormorant-days) comes from standardised daily counts but such frequent counts are not always possible and so most field data are a compromise between the time available for its collection and the best (i.e. most biologically meaningful) interpretation.

Bearing this in mind, the frequency at which counts are carried out should be adapted to the requirements of any study, the use of the waterbody by

Cormorants, and the variation in their daily presence there. As a general rule, it is recommended to schedule counts as follows. First, once every week or every ten days at fisheries/feeding areas of little apparent interest to Cormorants, or where Cormorant presence is known to be pretty constant. Second, two or three times per week at fisheries/feeding areas where Cormorant presence is heavy or when Cormorant presence is highly variable (e.g. during migration periods). Finally, counts should be conducted every day at fisheries/feeding areas where damage prevention is carried out by means of lethal or non-lethal techniques in order to assess effectiveness.

The potentially large movement (or ‘turnover’) of Cormorants at specific sites is difficult to capture in most counts. Being familiar with the local situation and phenology helps to quantify this aspect in planning counting regimes.

For example, at Loch Leven in Scotland, based in part on the movements of radio-tracked Cormorants, it was estimated that the actual number of birds passing through the site was probably ten times the mean number counted there at any one time (Wright 2003). Similarly, using re-sightings of ringed birds and concurrent systematic counts of Cormorants at a roost in Lake Geneva, Frederiksen *et al.* (2003) estimated that the site was actually used by 66% more birds over the season than were recorded there during the peak count. These two labour-intensive studies perhaps give the main message of this section — that counts of Cormorants at any particular site are, in effect, just snapshots of the actual situation there. Clearly, the more frequently these snapshots are taken, particularly during the main periods of Cormorant movement, the more accurate the picture of Cormorant numbers at any one site. Similarly, even ‘complete’ counts at a site are merely a piece of a much larger jigsaw — the ultimate size of which is determined by the frequent short- and large-scale movements of birds on both a daily and seasonal basis.

It is important to note that the ‘turnover’ of Cormorants may well have little influence on the total number of ‘Cormorant-days’, or ultimately on the estimated ‘impact’ on fish stocks, calculated for a

foraging site (see above) because birds leaving are likely to be merely replaced by other individuals and thus the maximum number on the site at any time will remain fairly stable.

However, these examples highlight that day-counts at foraging sites are not suitable or recommended for assessing Cormorant ‘population’ numbers on a wider scale, where coordinated simultaneous roost counts may be more appropriate.

Given the intrinsic difficulties described here of attempting to count highly mobile birds such as Cormorants, there are two other situations where Cormorants can be counted. Cormorants (at least, sexually active adults) congregate in colonies to breed and during the rest of the year all birds gather on roosts to spend the night. The previous sections describe how to take advantage of the social behaviour of the birds in order to best assess their numbers.

3.5 Estimating breeding success

In this section, we discuss some central ecological issues relating to Cormorant population dynamics. These include such questions as How many ‘active’ nests are there in a colony? How many eggs/young are there in the nests? How many young survive to leave the nest (i.e. ‘fledge’)?

An important aim of any study of avian breeding success should be to obtain estimates that are comparable both between colonies and between years. Whilst the most relevant parameters to record depend on the specific aims of the

study, arguably the most useful single parameter to obtain (e.g. for estimating total production of young and for inclusion in population models) is the number of young that fledge per egg-laying pair, as this perhaps best represents reproductive output per breeding female. We define ‘fledging’ here as young birds leaving the nest, and not the subsequent independence of the chicks from the adults which can often be problematic to determine.



Figure 3.10 Nest with newly-hatched chicks and eggs.

Photo courtesy of T Bregnballe.

In the following we describe methods that workers should use to obtain an estimate of the number of young fledged per egg-laying pair (referred to as ‘fledgling production’) or of brood size around the time of fledging (referred to as ‘brood size’). The description and recommendations are mainly based on Newson & Bregnballe (2003).

3.5.1 Fledgling production — Multiple observations of individually recognisable nests

The best method to estimate the number of young fledged per egg-

laying pair is to follow individually recognisable nests from egg-laying (or early incubation) until all chicks have reached fledging age.

Where multiple visits can be made to a colony, nest failures (i.e. those breeding attempts for which success = zero) can be identified and included in the calculations. Therefore, multiple visits allow estimates to be produced that are a good reflection of reproductive output per nest or clutch and, as such, allow for reliable between-year and between-colony comparisons.

Minimising disturbance

All unnecessary visits inside a colony during egg-laying and incubation should be avoided because disturbance at this stage can result in nest desertion. Disturbance also increases the probability of egg and chick predation (e.g. from gulls *Laridae* or crows *Corvidae*) as well as mortality through chilling or heat stress. Visits inside a colony should always be kept to an absolute minimum, with parents disturbed for no longer than 30 minutes, preferably less. Where there are chicks of four weeks of age or older, disturbance could potentially force premature fledging, so unless it is necessary to enter the colony, observations should be made from a distance using a telescope. If data cannot be obtained without entering a colony and you have no previous experience ask for advice or read Blackburn (1999).

Whenever possible, visits (where disturbance is unavoidable) should be made at dawn or mid-late afternoon before, or after feeding, to reduce food loss from chicks by regurgitation (see Hughes *et*

al. 1998). Some researchers have found that disturbance can be kept low by visiting ground nesting colonies at night.

Timing and number of visits

It may be useful to visit the colony prior to the expected egg-laying stage to estimate the best date for the first recording. This can be assessed by examining the stage of breeding birds (i.e. whether they are nest building, incubating etc.). In this way the worker could also gather additional information about the timing of breeding in that particular year. Timing of breeding can vary significantly between years for individual colonies and between colonies in a particular year (e.g. Newson *et al.* 2005).

The colony should be visited regularly from egg-laying to fledging. If this is not done, information about the losses of both clutches and broods can not be collected. Even where regular visits to a colony throughout the season can be standardised, factors out of the researcher's control (e.g. nest collapse rates, which are likely to differ between colonies and years due to changing environmental conditions) can have a large affect on production estimates even if the actual fledging production of successful nests is constant. However, if monitoring broods at regular intervals throughout development is possible, this should reduce the risk of such errors.

Obviously, visiting the colony at a time when the majority of nestlings are close to fledging will provide the best estimate of fledging production for successful nests (i.e. nests that have not failed before

this time, and go on to fledge one or more young). However, if the colony is visited at a time when nestlings are at an advanced stage, the oldest chicks in a brood may already have fledged and be sitting away from the nest and so not be included in records of nest contents.

Monitoring nests at an advanced stage may also be difficult at ground-nesting colonies where older chicks are likely to wander from their nests, making estimation of brood-size difficult. There is obviously a trade-off between collecting reliable data and keeping researcher effort and colony disturbance to a minimum. However, visiting a colony at about ten-day intervals should result in little loss of data.

Mapping of nests

Breeding attempts are sometimes initiated later in the breeding season some time after most pairs have already started to breed, often by younger or less experienced breeding birds. In order to identify and include any such breeding attempts, it is necessary to map all nests in the sample area and highlight the ones being monitored (see Figure 3.11). In ground-nesting colonies in particular it



Figure 3.11 Sketch from a section of one nesting tree within a Cormorant colony. Drawing courtesy of J Gregersen.

may be necessary to provide visual markers within the colony to enable individual nests or colony sections to be re-identified on subsequent visits.

Sample size

If the fate of only a few individually recognisable nests is being followed until chicks fledge, it may also be helpful to record brood size for a larger number of nests during the colony visits prior to fledging. Although, it is not possible to combine the two data sets and analyse them statistically, it can provide useful information on the concordance between the mean brood size at/near fledging in the nests monitored throughout the breeding season and the mean brood size at/near fledging in nests that were not monitored.

Specific areas within a colony are likely to differ in their 'quality' and as such, experienced and inexperienced birds are not likely to be distributed at random (van Eerden *et al.* 1991, Bregnballe & Gregersen 2003, Kopciwicz *et al.* 2003, Krag 2003). For this reason care should be taken to sample from several subsections within the colony. Ideally, one should aim to collect data from at least 30 nests from any discrete section of the colony.

What to record during visits?

Position of nests. For tree-nesting colonies it can be relevant to record where on the tree the nest is located. This is because the quality of different areas of the colony and/or birds present in different areas of a colony may differ. For ground-nesting colonies it can be relevant to record whether or not the nest is in the periphery of the colony or near to its core. This is because some studies have shown that nests

in the periphery are more exposed to predation than those closer to the centre (Siegel-Causey & Hunt 1981, Quintana & Yorrio 1998).

Clutch size. Collecting information on clutch size (i.e. number of eggs per nest) can become relevant if workers find differences in brood sizes at fledging and want to know whether these are likely to be consequence of differences in the number of eggs laid or a consequence of differences in partial chick loss. However, if the aim of research is merely to estimate the number of young fledged per egg-laying pair, clutch-size data do not need to be collected.

Ageing of chicks. Where hatch dates are not known, the age of Cormorant chicks can be determined in the field according to both their size and feather development (van Rijn *et al.* 2003). The downy feathers start growing from about the 6th day after hatch. At 10–14 days the chicks are covered by brown-blackish woolly down, and growth of the tail and flight feathers starts from about 14–20 days of age (Olver & Kuyper 1978; del Hoyo *et al.* 1992). The chicks stay in the nest till they are about 50 days old and fledged.

Predators. To help interpret colony and/or year-to-year differences in estimates of fledgling production, it is often very helpful to have knowledge of predators in the vicinity of the colony and the extent of their predation. It is therefore useful to record the presence of potential predators and any incidents or indications of predation. Cormorant eggs and chicks are potentially exposed to a



Figure 3.12 Chicks of different age — from just hatched to just fledged. Photos courtesy of Stef van Rijn.

1. Eggs and nestling of 0–1 days old (colony of Enkhuizen, IJsselmeer area, the Netherlands 24 April 2006),
2. Nestlings of 5–7 days old (colony of Enkhuizen, IJsselmeer area, the Netherlands 24 April 2006),
3. Nestlings of 10–12 days old (colony of De Kreupel, IJsselmeer area NL 14 April 2006),
4. Nestlings of 18–20 days old (colony of Kivilaid, Estonia 17 June 2007),
5. Nestlings of 23–26 days old (colony of Pohja Malusi, Estonia 19 June 2007).

number of predators. In tree-nesting colonies it is common that Magpies *Pica pica* and Crows predate eggs. Foxes *Vulpes vulpes* and Martens *Martes spp.* may also be important predators in some colonies.

In ground-nesting colonies, gulls are usually the main predators of eggs and nestlings. Great Black-backed Gulls *Larus marinus* (but also Herring Gulls *Larus argentatus* and Lesser Black-backed Gulls *Larus fuscus*) are particularly known to take Cormorant chicks. Great Black-backed Gulls may take chicks up to an age of at least 35 days. Foxes may also predate eggs and chicks if they are present on nesting islands or if they can gain access to it when Cormorants are breeding. In some countries (e.g. Finland, Russia, Estonia, Germany, Sweden and Denmark) White-tailed Sea Eagles *Haliaeetus albicilla* may occur as predators of young, and occasionally adult, Cormorants (Koryakin & Boyko 2005, Leihikoinen 2006).

Weather. It is often also helpful to make notes about the weather

up to, and during, the breeding season. For example, a particularly harsh winter may explain the late onset of the breeding season, whilst heavy rain and/or high winds may cause the sudden loss of clutches.

Analysis of data

Where multiple visits are made to a colony, the easy option is to calculate and report (1) the number of young raised to fledging (or as near to fledging as possible) per egg-laying pair; (2) the proportion of clutches that were unsuccessful (i.e. the proportion from which no young fledged); (3) the brood size around the time of fledging (only including nests that had at least one young); (4) the proportion of unsuccessful nests that were so because all eggs were lost and the proportion that were unsuccessful because all chicks died before fledging. Another possibility is to apply a modification of the Mayfield Method (Mayfield 1961, 1975) or a similar approach, to account for partial brood losses (as in Newson & Bregnballe 2003). Improved methods now exist for relaxing the assumptions of the Mayfield method (such as assumed constant survival over a specified period) and for accounting for potentially important sources of variation in nest-survival data (e.g. Rotella *et al.* 2007). Use of the Mayfield Method increases standardisation and comparability of fledging production estimates. When reporting results, it is important to state the limitations of the data (e.g. sample size, representativeness of sample) and any assumptions made (e.g. assumed constant nestling survival over specified period) in the analyses.

3.5.2 Fledgling production: a single visit to the colony

Some researchers judge this method to be inappropriate for estimating mean fledgling production per nest or clutch. Nevertheless, where multiple visits to a colony are not possible, data collected on a single visit can still provide an important indication of breeding success in a particular year.

One of the uncertainties of this method is that mean brood size estimated from a single visit will be strongly dependent on the stage of nestling development at the time of the visit. Therefore, the age of chicks should be estimated for nests where brood size is recorded. Furthermore, even though the number of empty nests is recorded in the section of the colony sampled, it will not be possible to obtain a precise estimate of the number of complete losses of eggs or chicks. Thus nests where all eggs were lost or all chicks died may have disappeared prior to the visit and some empty nests may be empty because the young had fledged and left the nest (see below).

Field method

The observer should aim to visit the colony when the majority of chicks are 30–40 days old (see above concerning minimising disturbance). Brood size should be noted for as many nests as possible and mean age of the chicks estimated for each brood. Within selected sectors of the colony, all nests within the following categories should also be recorded.

Those apparently empty nests where (a) all eggs or chicks have

been lost (cold eggs or dead chicks may still be present in the nest); (b) the chicks have fledged and left the nest, and (c) eggs or small chicks are present (but not visible) and the parents are absent. Be aware that adults may sit in empty nests (e.g. deserted nests and nests from which chicks have fledged earlier in the season).

Estimates, assumptions and decisions

To estimate the number of young fledged per egg-laying pair or per nest, the estimated proportion of nests that produced at least one fledged chick (i.e. the proportion of successful nests) is multiplied by the estimated mean number of chicks assumed to fledge per successful nest.

A number of decisions have to be made when estimating the proportion of successful nests.

For the apparently empty nests (see a-c above), a decision must be made as whether or not to assume that nests appeared empty because (i) the chicks had fledged and left the nest; (ii) all eggs or chicks had been lost; or (iii) eggs or chicks were present but invisible to the observer. The proportion of empty nests that were so because the chicks had fledged and left the nest may be estimated from observations of presence of fledged chicks (i.e. those not sitting in nests) inside and outside the colony. It may be reasonable for some colonies and years to assume that the majority of the late clutches or broods with small chicks will be lost before fledging. Some studies show that few of the very late clutches in Cormorant colonies produce fledged young (Bregnballe 1996).

For the nests containing eggs or chicks, a decision must be made as to how best to estimate the probability that the breeding attempt will be successful (i.e. that at least one of the chicks in the nest will fledge). A decision must also be made as to whether mean brood size (e.g. of 35–45 day old chicks) provides a fair estimate of brood size at fledging. These decisions (basic assumptions) must be

mentioned in full when reporting the results of the estimates.

Analysis and reporting of data

When analysing data, workers should combine an estimate of the proportion of nests that produced no fledged chicks with an estimate of the number of chicks fledged in nests where at least one chick did fledge. As always, it is important to state the limitations of the

data when reporting results. For example, if mean brood size is recorded prior to fledging, it is important to report the ranges of ages included (e.g. 35–45 day old chicks), the mean age of chicks and the variance around this measure. As timing of breeding will vary between years and colonies, it can be difficult to obtain comparable estimates of brood size from a single visit each year.

4 CORMORANT DIET, FOOD AND ENERGY INTAKE

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4.1 Introduction

From their prey choice as assessed from dietary studies, Cormorants are known to be more or less generalist predators. This means that they usually consume the most abundant fishes or those that are most easy to catch at a particular foraging location. Usually the composition of the prey taken by Cormorants and that present in the foraging location are fairly similar and so the composition of the birds' diet can give a reasonable picture of the fish stock and its composition in the waters where the Cormorant has foraged (e.g. Hald-Mortensen 1997, Carss & Marquiss 1997).

There are several different methods available to those who want to assess Cormorant diet. Birds can be observed foraging, cast oral pellets (containing hard, undigested prey remains) can be collected and analysed, as can regurgitations (containing partially-digested 'meals') collected at roosts or, most commonly, from nestlings during visits to the colony. Finally, the stomach contents of dead (usually shot) birds can also be examined.

Here, we discuss these different methods and highlight the advantages and disadvantages

of each, following Carss *et al.* (1997) carefully. This paper (from Wetlands International's Cormorant Research Group) attempts to reach consensus on methods and is used by researchers across Europe and beyond. In this chapter, we pick out the salient parts of the Carss *et al.* (1997) review but would also urge interested readers to consult the original paper directly. Despite the fact that the review was published over a decade ago, much, if not all, that it says on both the notion of rigorous scientific data on Cormorant diet and food intake (and hence, the need for standardised methodologies), and the rationale for obtaining such data in relation to the ongoing public debate about Cormorant 'impacts' at fisheries, is still highly relevant today. Given this, we have occasionally quoted sections of Carss *et al.* (1997) verbatim in this chapter but always with the relevant citation.

This chapter is presented in two parts. The first covers methods of assessing diet, the second takes this dietary information a step further and considers the conversion of fish as food to fish as energy — the ultimate requirement of all living things. Energetic considerations are important for several reasons, perhaps most importantly they will influence both the 'quality' of an individual (i.e. its capacity to fly, move between habitats, breed etc.) and how much prey a Cormorant eats, its daily food intake. This is an important biological issue when considering predation at fisheries but such information also has political value (see Text Box 4.1).

In relation to Cormorant diet, the choice of method will depend on the aim of the research, the time available and the amount of funding available (see also Table 4.1).

Table 4.1 Basic information provided by different methods of Cormorant diet assessment. Yes = Y, No = N, Potential bias = ?; further methods concerning daily food intake can be found in section 4.7 (Bioenergetics).

| | Observations | Pellets | Stomachs | Regurgitates |
|---------------------|--------------|---------|----------|--------------|
| Prey species (list) | ? | Y | Y | Y |
| Species composition | N | Y | Y | Y |
| Fish length/weight | Y (?) | Y (?) | Y | Y (?) |
| Daily food intake | N | Y (?) | Y (?) | N |

To observe Cormorants while they are foraging needs, above all, time, but the method is restricted to recording only those fish that the bird brings to the surface to swallow as small fish are often swallowed underwater (Strod *et al.* 2003). For those fish brought to the surface, it may be possible to identify both the species involved and to estimate its length. The use of such methods is somewhat limited but if an observer wanted to assess the hunting success of Cormorants on a water body with a known fish stock (e.g. a Carp *Cyprinus carpio* pond) this could be a good method. It also has the advantage that it should not be a disturbance to the birds.

Collecting pellets under roosts or colonies is quite easy, but it takes considerable time to analyse them and a reference collection of fish bones and other hard parts is almost certainly required. There are serious concerns over possible biases in this method, as some hard parts may not survive the digestion process (being digested completely or severely eroded by it). Nevertheless, pellets are still a useful sampling technique because they potentially sample a large number of individual birds through time. One sample may thus contain pellets originating from several days before. Bearing in mind the potential biases in the method, pellet analysis can give a broad, relative (at least qualitative) overview of which fish species are eaten in a particular area. It is possible to estimate the length of fishes from their remains in pellets but this requires considerable effort and is restricted only to those hard parts that show little sign of digestion (erosion). As each bird produces one pellet

Sometimes claims of ‘impact’ are contested. Thus, as well as being of scientific interest, knowledge of Cormorant diet (linked — through an understanding of fish biology and fisheries science to — ‘impact’) also has political value. This is particularly true where there are calls to control bird numbers in order to protect fisheries. As Carss *et al.* (1997: 198) point out:

‘There are calls to devise a pan-European management plan for Cormorants and to ‘control’ birds by culling, despite the scarcity of scientific evidence for any detrimental effects of fish predation on natural water bodies. Attempts to provide such evidence, for any fishery type, in any country, necessarily require rigorous estimates of diet, including such things as fish species composition and size distribution. Moreover, knowledge of foraging ecology is also essential when assessing possible impact, particularly information on daily food (and energy) requirements, diet shifts, prey selection, the influence of foraging habitat, and any seasonal and annual variation. Thus knowledge of Cormorant diet, food and energy intake has both scientific and political value.’

Text Box 4.1 Knowledge of Cormorant diet is an essential element to assessing any potential impact of these birds at fisheries.

per day (Zijlstra and van Eerden 1995), the method has been used to reconstruct daily food intake.

In old, established colonies or roosts, sample collection should be restricted to the early morning because during the day other mammal (e.g. Foxes *Vulpes vulpes*, Wild Boar *Sus scrofa*) or bird species (e.g. Coot *Fulica atra*, Gulls *Laridae*, Herons *Ardeidae*) can feed on the leftovers from the Cormorants. The collection of these samples causes no, or very little, disturbance for the Cormorants. In many situations, for example large, extensive lakes or large rivers, where observing foraging birds is difficult, areas where birds cannot be shot, or during non-breeding period, pellets may be the only means of assessing the food of Cormorants.

In many ways, regurgitations — often produced by nestlings or

older birds as a defence reflex when disturbed — can be treated in the same way as stomach contents. The assumption being that the bird has regurgitated the full contents of its stomach. Possible bias occurs as regurgitated material may consist of the larger fish taken. Partially-digested material from earlier feeding trips may not be included in regurgitations. Stomach contents analysis obviously requires dead birds (most often shot), and these may not always be available. The work involved in regurgitation or stomach contents analysis is slightly more onerous (and smelly) than that for pellets. However, because stomachs and regurgitations often contain relatively fresh food material, this method — if used carefully — probably gives the best assessment of Cormorant diet in terms of both prey composition and size-distribution of fishes.

4.2 Feeding observations

As Carss *et al.* (1997: 209–210) point out, ‘Direct field observation of foraging Cormorants to record the prey they consume has several advantages. It is non-destructive and can provide large amounts of data with little disturbance to the birds. A major advantage over other methods is that spatial and temporal variation in diet might be assessed with some accuracy (Davis & Feltham, 1996), with data on prey and precise feeding locations being collected simultaneously. In addition to dietary information, observations can also provide data on diving behaviour and an index of foraging performance. It may be difficult to get close enough to birds to enable the identification of all prey items caught during a feeding bout. Biases will be further compounded if particular prey species are more, or less, easy to recognise. This problem may be particularly acute at fisheries with a diverse fish fauna. It may be possible to reduce such potential biases by categorising fish on their type (e.g. Cyprinid/flatfishes, Davies & Feltham, 1996) or body shape. Errors could also occur when attempting to estimate the size of fish caught, especially when judging the lengths of smaller prey items, which generally have shorter handling times. The sizes of fish caught by birds during observations are usually estimated in relation to bill or head length. Despite the common use of this technique, there have been few attempts to quantify observer bias under experimental conditions. The possibility of birds swallowing items underwater must be considered. The frequency at which this occurs has yet to be fully quantified.’

However, in captivity, experiments have demonstrated incontrovertibly that Cormorants can swallow fish (of maximum length 8 cm in this case) underwater (Strod *et al.* 2003). Thus, given this potentially serious error in diet assessment, it is not possible to determine Cormorants’ daily food intake from direct observations.

4.3 Pellet collection and analysis

Cormorants regurgitate the undigested parts of their prey (e.g. bones, scales or ear-stones ‘otoliths’) as oral pellets, covered in mucus and produced from the stomach lining (Figure 4.1). Pellets are relatively easy to collect under night roosts or in breeding colonies and are sometimes the only available means of assessing the food of Cormorants. This is

a useful method of obtaining a description of their diet in (at least) qualitative terms. It is possible to estimate the daily food intake of birds by this method but only if one can quantify the rate of erosion of material recovered from pellets. Care must be taken when interpreting the results of pellet analyses as there are serious potential biases, erosion of otoliths and other hard parts being one of the main potential errors.

4.3.1 Collection and conservation

Pellets should be collected as soon as possible after they are produced



Figure 4.1 Two Cormorant pellets, the undigested fish bones can clearly be seen within the mucus coating of the pellet. Photos courtesy of S van Rijn.

by the birds. Ideally they should be collected as soon as the Cormorant flies off. The area must be inspected thoroughly in order to recover the small pellets as well as it is thought that large pellets are often more commonly found and collected by researchers as they tend to be easier to locate. Pellets should also be intact, especially if collected from beneath trees where the fall may cause them to disintegrate. During collection, each pellet must be kept separately in a plastic bag and they can then be held in a deep freezer for a longer period of time. This is necessary when one wishes to compare individual meals of individual birds. Mixed samples can be collected if only a qualitative description of the prey species composition and size of a wider 'population' of birds is needed. It is possible to collect pellets at daily or longer intervals depending on the research question.

4.3.2 Preparation and analysis

Pellets, previously kept frozen at -20°C , can be placed at room temperature for a few hours to thaw. They should then be removed from the plastic bag and placed into a Petri dish and the bag washed out with water passed through a 0.3 mm sieve, any remains can then be added to the rest of the pellet in the Petri dish. This process is time-consuming but is important because some pellets fall apart during thawing and can get stuck inside the plastic bag. The distinctive undigested items in pellets (Figure 4.2) must then be examined under a stereomicroscope.

Otoliths and other bony identifiable parts such as pharyngeal bones,

chewing pads, lower jaws or vomers are picked out manually using fine tweezers. Fish scales should only be picked out if there are no other structures present. Within individual fish there are actually three pairs of otoliths and some of these chalky-looking structures are relatively easy to identify, count and measure when extracted from pellets. In the case of Cyprinid (Carp family) fishes, the large otoliths recovered in pellets are either the asterisci or lapilli, whereas the otoliths from other groups of fishes are usually the sagittae. The eye lenses of fishes are also often found in pellets. Although it is seldom possible to identify the fish species from these structures, lenses can be counted (to estimate the minimum numbers of fish) if they outnumber the other undigested key remains. It is not necessary to disinfect the otoliths or most other hard parts but the pharyngeal bones can be dipped into a 3% solution of hydrogen peroxide (H_2O_2) for a few seconds and dried afterwards if required.

In some instances, pellets may be difficult to tease apart and so they can be dried at room temperature for a few days before being 'crumbled' carefully into a Petri dish. Alternatively, they can be soaked in an enzymic washing powder or NaOH solution to dissolve the binding organic mucus matter. This approach avoids the possibilities of smaller otoliths or other remains being overlooked in any folds in the mucus pellet. A 9% NaOH solution (90 g of granules dissolved in 1,000 ml of water) or a saturated solution of 'biological' (enzymic) washing powder should be poured over



Figure 4.2 A dissected Cormorant pellet.

Photo courtesy of J Trauttmansdorff.

the pellet and left until the next day (for 15–20 hours) by which time the mucus has dissolved and becomes transparent. The solution is then passed through a 0.3 mm sieve and all the remaining otoliths and other undigested remains can be picked out. Care must be taken with the use of NaOH as it is capable of dissolving or softening some important structures such as chewing pads and bones.

Pellets will almost certainly contain the remains of several fishes and it is often possible to both identify these to species level and to estimate their original size by careful examination of key bones recovered from the pellets. Many of these key bones occur in pairs within individual fish (i.e. right- and left-handed bones from either side



Figure 4.3 Dried contents of a Cormorant pellet extracted from mucus.

Photo courtesy of J Trauttmansdorff.

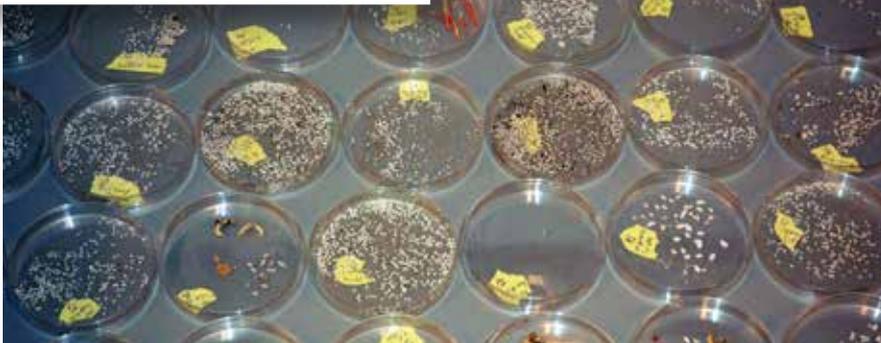


Figure 4.4 Dried contents of Cormorant pellets (mostly otoliths) awaiting identification, measurement, and counting.

Photo courtesy of S van Rijn.

of the fish). The commonest key bones recovered from pellets are the pharyngeal teeth of Cyprinids, lower jaws (dentaries) of other groups, and the ear stones (otoliths) of all species. Other remains commonly recorded include vertebrae, vomers (bones from the roof of the mouth in many species), chewing pads from Cyprinids, eye lenses, and fish scales.

The size of many of these hard parts can be measured when dry (Figure 4.3), and these measurements used to estimate

the original length of the fish by use of standard bone length:fish length equations, although precise errors associated with this are currently unknown (Carss *et al.* 1997). With practice, these key bones can be picked out of pellets, where necessary they can be paired (i.e. right and left bones of the same species and size and so assumed to be from the same individual). For example, where a pellet contains four small left otoliths, three small right ones, and a further two large right otoliths, the record for this pellet should be

four small fish and two large ones (i.e. six individual fish in total). In all cases, the number of fish recorded in a pellet is determined on the basis of the most numerous structure found in the undigested remains. It is not always possible to determine the species represented in pellets by examination of their otoliths, particularly if these are partly dissolved (eroded through the action of digestion). And so (in the absence of such species-specific structures such as pharyngeal teeth) these records should be reported as 'unidentified Cyprinid' for example. However, species can be determined by careful examination of pharyngeal bones and chewing pads (see section 4.3.3).

Ultimately, the minimum numbers of each fish species

can be recorded for each pellet. Thus for each specific sample of pellets collected, a cumulative total of the numbers of individual fish of different species can be recorded. There are several ways of presenting the results of pellet analysis, each giving a slightly different picture of Cormorant diet. At its simplest, it is possible to record the presence/absence of different species in the pellets. These data can be presented as frequency of occurrence, either 'percentage frequency' (the proportion of pellets containing a particular species) or 'relative frequency' (the number of occurrences of a particular species as a percentage of all recorded prey items). Both frequency of occurrence methods give a picture of Cormorant diet, either in terms of the proportion of pellets containing species X or the proportion of all identified fishes that comprised species Y. For percentage frequency, the total used is the number of pellets and the frequencies will not sum to 100% (as pellets can contain remains of more than one species). For relative frequency, the total used is the number of recorded occurrences and the frequencies will sum to 100% (see e.g. Dirksen *et al.* 1995; Keller, 1995; Veldkamp, 1995).

Researchers also often derive fish body length from the measurement of key bones found in pellets, using either published equations or ones derived from local samples of reference fish. They then convert fish size estimates to ones of fish weight (again using published or reference equations). In this manner (see section 4.3.4), the total estimated biomass of fish

represented in the pellet sample can be assessed, and each species can be assigned a proportion of this.

4.3.3 Recognisable structures — key bones in pellets

The pharyngeal bone is the ossified fifth gill arch of Cyprinids and loaches (Cobitidae), and its shape, size, and the position of teeth on it are species-specific. There are several published keys to aid identification (e.g. Horoszewicz 1960, Rutte 1962, März 1987, Leopold *et al.* 2001). Several of these keys also include advice on how best to measure these bones and which equations to use to convert these measurements to estimates of original fish length. Some examples are shown in Figure 4.5.

The pharyngeal bones (PB) can be classified as left (PBl) and right pharyngeal (PBr) and the lengths PBL1 and PBL2 can be measured for both. PBL1 is the length between the ventral and dorsal tips of the bone and PBL2 is the length (width) between the dorsal tip and the lateral process. With these measurements it is possible to pair-up right and left pharyngeal bones and thus to estimate the minimum number of fish represented by pharyngeal teeth in pellets. The additional measurement PBL2 can also be used because pellets often contain pharyngeal bones that have broken ventral tips, and so relying only on the PBL1 measurement can lead to an underestimate of the original fish length.

The chewing pad (CP) is an odd structure found only in Cyprinids, being part of the pharyngeal

structure — the basioccipitale bone (see Veldkamp 1995 for more details). The length (CPL) and the width (CPW) of the chewing pad should be measured. It should be possible to measure the maximum width and the maximum length of the chewing pad, bearing in mind that this structure has specific shapes in different taxonomic groups (e.g. Chub).

Otoliths (or statoliths) are pairs of structures in the inner ear of bony fish. The lapilli are found in the utricle, the sagittae in the suctulus, and the asterisci in the lagena within the skull. As fish are digested, the skull breaks down and the otoliths become separated and are clearly visible within pellets (as small white 'stones'), whilst most (if not all) of the other bones of the skull are completely digested. The sagittae are generally the biggest of the three types of otolith in most fish species, except for the Cyprinids where the asterisci are the largest otoliths. The asterisci otoliths from Cyprinids (OLA) can also be classified as either left or right and, with the help of measurements, can be paired-up to represent single fish. Otoliths must be examined very carefully to exclude any that show signs of erosion and those showing no signs of digestion can be measured from the anterior to posterior ends. The lapillus otoliths of Cyprinids (OLL) can not be categorised as being either left or right as they are often too small. Nevertheless, they can be counted (and this number divided by two to obtain the minimum fish number) and measured as described above.

For other taxonomic groups (e.g. Brown Trout *Salmo trutta*, Grayling

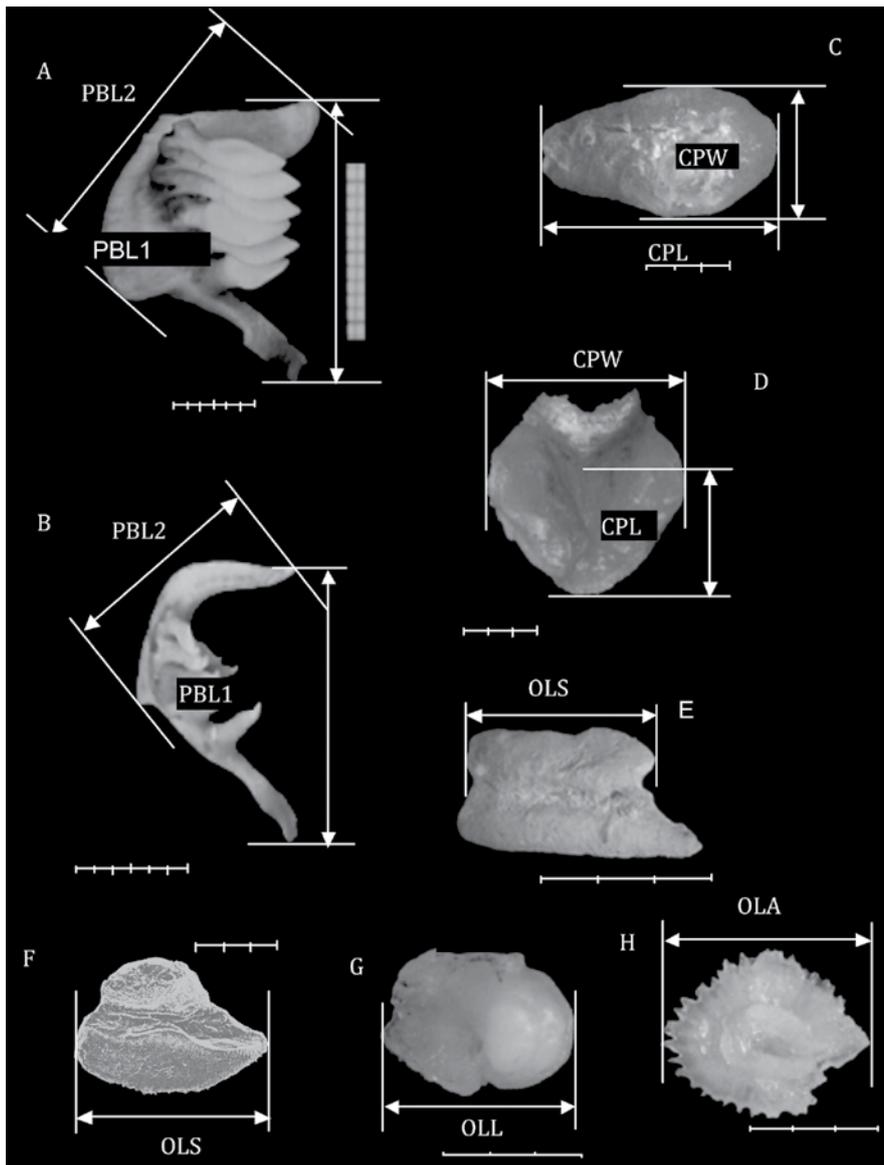


Figure 4.5 Measurements of biometric parameters of 'key bones' used in diet analysis. **A**–pharyngeal bone (PB) of a Nase *Chondrostoma nasus*, **B**–pharyngeal bone of a Chub *Leuciscus (Squalius) cephalus*: PBL1 and PBL2–lengths of the PB; **C**–chewing pad (CP) of a Danube Roach *Rutilus virgo*, **D**–chewing pad of a Chub; CPW–width of the CP, CPL–length of the CP; **E**–sagitta of a Grayling *Thymallus thymallus*, **F**–sagitta of a Brown Trout *Salmo trutta*: OSL–length of the sagitta; **G**–lapilus of a Cyprinid: OLL–length of the lapilus; **H**–asteriscus of a Cyprinid (Chub): OLA–length of the asteriscus. Throughout, one unit of measurement corresponds to 1 mm. Photo courtesy of M Govedič.

Thymallus thymallus, Pike *Esox lucius*, Perch *Perca fluviatilis*) the sagittae otoliths (OSL) can be classified as either left or right and the whole length of the measured as above. Other commonly recorded key bones include the lower jaws of Trout, Perch, Pike and Pikeperch

(*Sander lucioperca*) which can be used for species identification, as can the opercular bones of Perch and Pikeperch, and the vomers of Trout and Grayling. Specific keys for the identification and measurement of these bones have been published (see Figures 3.8 and

3.9, also e.g. Horoszewicz 1960, Rutte 1962, Wise 1980, März 1987, Libois & Hallert-Libois 1987, Libois *et al.* 1988. Petrova & Zivkov 1989, Mehner 1992, Leopold *et al.* 2001, Schulz-Mirbach & Reichenbacher 2006). There is also an AFORO online database for otolith identification — see www.cmima.csic.es/aforo/index.jsp

During pellet analysis and subsequent interpretation of data, it must be remembered (Carss *et al.* 1997: 199–200) that 'pellet analysis is a useful method of obtaining a rough index of Cormorant diet in qualitative terms but there is serious doubt as to whether it can be used to derive quantitative information on, for example, the species composition or size-range of fishes taken. With reservation (in particular relating to the under-recovery of small fish), pellets may be used to investigate spatial or temporal variation in the relative frequencies of particular prey species of varying provenance. However, great care must be taken when interpreting the results of such studies as there are serious potential biases.' Nevertheless, some studies (e.g. Dirksen *et al.* 1995) have used the results of pellet analysis to estimate total fish consumption by Cormorants.

4.3.4 From otoliths and other bones to diet composition

In order to reconstruct fish length from measured otoliths or other bones it is necessary to have regression formulae of bone length to fish length. Subsequently fish mass can be estimated from fish length

using other regression equations. All species of fish have different regression formulae, often depending on season and local forms. If one is carrying out a major study on diet, it is best to base this analysis on regression equations derived directly from local fish. Short-term or incidental studies tend to use regression formulae taken from the literature (e.g. Govedič *et al.* 2002, Przybylski 1996, Wise 1980).

The bony structures used for species recognition are linearly correlated to fish length and in a semi-log way to fish weight. The lengths of fish should be measured up to the nearest 1 mm and the body mass to 0.1 g precision. Three lengths should be measured: standard length (SL), fork length (FL) and total length (TL) (Ricker 1979), but only the total length (TL) is to be used to derive the regression equation. To measure the total length of the caudal fin, it should be squeezed and the length at maximal extension measured (Ricker 1979).

As discussed in section 4.3.2, it is a good idea to explore the size-distribution of fish eaten as well as to examine the diet based on numerical and mass proportions by species. This is especially important when trying to compare the ‘importance’ of particular fish species — numerically, small 0+ (the young of the year) fish may be the most frequently eaten prey but, based on mass, a small number of larger (i.e. older) fish may contribute most to overall diet.

4.4 Stomach contents analysis

Carss *et al* (1997: 204–205) discuss stomach contents analysis in considerable detail, stating that

‘the following methods apply to the stomach contents of dead birds but also to regurgitations and samples obtained by stomach flushing. Daily food intake should not be determined from stomach contents analyses because it is not known whether a bird had stopped feeding for the day (when it was shot). Maximum values are overly influenced by subjective judgement of what constitutes a full stomach, and might overestimate daily intake by ignoring lower values.’

‘Stomachs (regurgitations and stomach flushings) often contain relatively fresh material but there are also well-established methods for dealing with well-digested prey. The differences between relatively fresh fish and the undigested but heavily eroded items at the bottom of the stomach are clear. Some of the more serious errors associated with such well-digested material (e.g. as in pellet analysis above) can be avoided. Sometimes, stomach contents may be the only way of assessing Cormorant diet if pellets cannot be collected or direct observations are difficult. Stomach contents samples can be accompanied by age, sex, and parasite infestation information for each bird, and they are also site-specific (i.e. foraging grounds are known) or can be implied from the location at which the bird was shot.’

‘There are several disadvantages to stomach contents analysis, most obviously the necessity of killing birds. Licences are required to kill Cormorants in European countries and so in most cases the samples available for analysis are small. The sampling unit for such analysis is an individual stomach, not the number of fish

it contains. Sample size may be further reduced if stomachs are empty, but this can be reduced by shooting birds later in the day after they have had a chance to feed (although this adds a bias if some prey are digested quickly or if there are diurnal variations in the prey selected.’

4.4.1 Collection and conservation

If researchers and hunters cooperate (e.g. within a management program), and carcasses are delivered for analysis, it is advisable to prepare a standard identification label, which can be filled out with the necessary information and fixed to the bird. This ensures that all the necessary information is recorded as soon as the bird has been killed, and that this information remains with the bird from the time it was shot. The more information that can be recorded for each bird, the greater potential of interpreting the subsequent results of stomach contents analysis. Table 4.2 shows the minimum information that should be recorded for each bird by the hunter and the person examining the carcass in the laboratory. Needless to say, time and place of shooting Cormorants will determine their diet and this can also lead to bias. Dead Cormorants can also be obtained through cooperation with fishermen who use gill nets. Such nets can kill (drown) Cormorants as they are foraging, so the method is useful in some circumstances.

Shot or other dead Cormorants should be examined as soon after death as possible or stored frozen (-20°C) as soon as possible.

Table 4.2 Minimum information to be recorded by hunters and scientists in relation to dead birds made available for stomach contents analysis.

| By hunter | By scientist |
|----------------------|----------------------|
| Date of shooting | Sex of bird |
| Time of shooting | Age of bird |
| Location of shooting | Total weight of bird |
| Type of water body | |

4.4.2 Dissection

After thawing and taking biometric measurements (see chapter 5) open

the body cavity with sharp scissors making an incision in the flank below the sternum which passes through the sternum and clavicle. The skin of the throat is then opened by cutting across the gullet just below the head and down the length of the neck to join the top of the initial body cavity incision. The body cavity incision is continued down the remaining length of the body to the vent. The trachea and various internal organs are then separated from the stomach, which can now be lifted out of the body cavity in its entirety and severed

from the hindgut. The stomach and the foregut including the proventriculus should be opened from the top to bottom (Figure 4.6).

Some researchers then weigh the stomach and its contents, and then also weigh the contents on removal. This latter measurement can be subtracted from the mass of the intact bird to give a more precise measurement (i.e. of the whole carcass minus the weight of any meal in its stomach) (see Table 5.1 and description of ‘net weight’ of body mass in section 5.4).



Figure 4.6 Two examples of opened Cormorant stomachs showing partially-digested food material. Photos courtesy of J Trauttmansdorff.

4.4.3 Analysis

Any whole fish should be removed carefully, identified and measured (length, weight). Carss *et al.* (1997: 207–208) propose a standard method for processing stomach contents, an edited extract of which is quoted here. ‘All remaining partially-digested material should be flushed out, using a water bottle, into a storage container. A saturated solution of biological washing powder should then be added which completely covers the stomach contents. The washing powder digests all the remaining flesh from partially-digested fish after about 4–6 days. The process can be speeded up by placing samples in an oven at about 37°C and stirring occasionally. Once samples are ready they should be poured into a fine sieve and rinsed well with cold water to clean and dislodge stubborn pieces of flesh or cartilage, and to disarticulate skeletons or skulls.’

‘Once thoroughly rinsed, bones should be transferred to filter paper for drying. Care should be taken to

ensure that all bones are collected, as fine vertebral spines and very small pharyngeal teeth sometimes become lodged in fine-meshed sieves. Samples should be air dried for 1–3 days before examination, alternatively they can be placed in paper packets after drying for storage and later analysis. Biological washing powder does not appear to damage bones and air drying does not lead to significant shrinkage of material over time periods of a few days-weeks.’

‘Analysis of the dried remains involves placing them in a Petri dish for examination under a low power binocular microscope. Key bones (described in section 4.3.3) can then be extracted. As with remains from pellets, the appearance of these key bones can be used for identification, and their size to estimate fish lengths and hence fresh weights from a series of regression relationships. For the most accurate assessments of diet, key bones must be robust and resistant to digestion, relatively easy to identify, and diagnostic. Thus it is recommended that care is taken when selecting potential key bones to record. For example, Feltham (1990) did not use otoliths from the stomach contents of Red-breasted Mergansers (*Mergus serrator*) because their presence did not correspond well with the presence (or size) of other bones from the same fish species.’

‘Finally, it should be remembered that the sampling unit for stomach contents analysis is not the number of fish recorded in a stomach but the stomach itself. Similarly, sample size is important as it may affect the accuracy of diet assessments — as has

been shown for both Goosander (*M. merganser*) and Cormorant stomach contents data. In Scotland (where the fish community comprises relatively few species) it has been concluded that ‘adequate’ estimates of diet were possible from samples of 12–15 stomachs containing food but more analysis is required from large samples of stomachs containing diverse fishes.’

Care must be taken when interpreting the records of all the (fresh and digested) material recorded in stomach contents. As Carss *et al.* (1997) state ‘In theory, the more digested the contents the greater the potential for bias, as some items will be less resistant to digestion than others and may thus be digested relatively quickly. Some workers have tried resolving this problem by examining only intact material. However, it has been shown for Goosander stomach contents, that smaller fish were under-represented by this method, probably because the digestion of fish is so rapid that small items can disintegrate while larger ones resist disintegration for longer. Studies examining diet from intact items alone will underestimate the proportion of small fish species and overestimate the mean size for some larger ones.’ Thus data from whole, intact, undigested fish should be included with those determined from the examination of key bones from partially-digested material.

As with pellet analysis, key bones can be identified to species level, counted (as pairs if necessary) and measured in order to estimate the minimum number of fish of different species within the

Very often different species of parasites (mostly nematodes) can be found in the pellets and in the Cormorant stomachs (see Figure 4.6). Take at least a sample of them and if you are not able to identify them immediately, put them in alcohol (70%) in a well-sealed vial.

Text Box 4.2 Parasites.

stomach. Similarly, bone lengths can be converted to estimated fish lengths, and estimated fish lengths to estimated fish weights through a series of regression equations (for example, see Appendix 1 in Carss & Ekins 2002). Data are then usually reported, on a species by species basis, as percentages — both by number and by mass. This dual approach to data presentation is important as often Cormorant diet comprises many small fish which contribute a lot to numbers but little to biomass. Conversely, most of the biomass in the diet can be the result of a small number of large fish. Through the careful measurement of key bones and the accurate use of regression equations, it is also possible to present dietary data in terms of the length-frequencies of different prey species. Such information can be enhanced further by reference to additional information from the location where the birds were shot (e.g. Russel *et al.* 2003, Trauttmansdorff 2003).

4.5 A note on regurgitations

When Cormorants are disturbed at a roost or in a breeding colony, they often vomit whole or partly digested fish which can be



Figure 4.7 Pictures of key bones from Chub *Leuciscus Leuciscus* (scales, praeoperculum, operculum, clavicle, pharyngeal bones).

Photo courtesy of J Trauttmansdorff.

collected from the ground below. Both whole and partially-digested fish can be treated in the same way as described for stomach contents analysis but there are potentially serious problems with interpretation. The samples collected from the ground may tend to be larger specimens (these are easier to find in dense undergrowth) and it is often not possible to determine which fishes were regurgitated by which bird (i.e. which fish correspond to the same ‘meal’) and this compromises the sample size. This is clearly not such a problem if regurgitations are collected at ground-nesting colonies or if they are collected from nestlings if trees are climbed to examine nest contents. With regurgitations produced by nestlings there is a further theoretical bias associated with the fact that adults might eat low quality food themselves and feed higher quality food (of different species and/or size) to their young. However data are currently unavailable to test this idea. Regurgitated fish can be used to calculate the regression lines needed to correlate otoliths and other key bones to total fish length (and mass, if specimens are completely intact).

4.6 Reference collection

Before analysing the diet of Cormorants in any detail, it will almost certainly be necessary to establish a reference collection of the key bones, what will allow the identification of the fish remains found in pellets, stomachs, or regurgitations. Not all keybones will be well-described in the literature and so making a reference



Figure 4.8 Pictures of key bones from Perch *Perca fluviatilis* (scales, praeoperculum, operculum, lower jaw, clavicle).

Photo courtesy of J Trauttmansdorff.



Figure 4.9 Pictures of key bones from Brown Trout *Salmo trutta* (praeoperculum, operculum, lower jaw, clavicle).

Photo courtesy of J Trauttmansdorff.

collection allows workers both to become familiar with bones and other structures from particular species, and also to prepare a number of ‘type’ specimens of different lengths (perhaps at 1 or 2 cm intervals for large fishes and

0.5 mm intervals for small ones). Such material will be invaluable when relating the length of bones found in diet samples to the original length of ingested fish (see earlier comments on regression equations). The most commonly prepared bones and other structures in a reference collection are probably scales, otoliths, praeoperculum, operculum, lower jaws, clavicles, pharyngeal bones (*Cyprinidae*, *Cobitidae*), chewing pads (*Cyprinidae*), vomers (*Salmonidae*, *Thymallidae*) and vertebrae. As examples, key bones from Chub, Perch and Brown Trout are shown in Figures 4.7–4.9.

4.7 Bioenergetics

How much fish does a Cormorant eat each day? This is a vital question in relation to the potential impacts of Cormorants at a fishery (see also chapter 10). Here we must first have rigorous estimates of both the number of birds feeding there (not necessarily the same as the number counted there at any one time, see chapter 3, section 3.4) and their diet there (in terms of biomass and the proportion that is of particular interest, see section 4.4.3). Crucially, we also need good quality data on the species composition, availability or abundance of their prey in the waters where they forage (see Part Two of the Field Manual).

4.7.1 Introduction

Turning to how much fish is consumed by Cormorants, this is a deceptively easy question to ask but a much more complex one to answer. We need to consider

how the act of feeding (as well as the type and ‘quality’ of prey) contributes to both the more general behaviour and ecology of the birds in the environment throughout the year, but also how much energy an individual bird spends on capturing a meal and how much energy it obtains from digesting and assimilating it. This complex inter-relationship between an individual’s physiology and its more general ecology and behaviour is termed ‘bioenergetics’. This is a complicated subject but one that is important to understand as we consider the ‘daily food intake’ (DFI) and ‘daily energy expenditure’ (DEE) of Cormorants.

All living organisms must obtain food from the environment from which they derive chemical energy to perform work, to maintain their structural integrity, and, ultimately, to reproduce. Hence, the quest for food is a fundamental driving force in determining animal behaviour. One highly relevant aspect of behaviour in relation to Cormorant–fishery interactions will be foraging behaviour and foraging site choice: the choice a bird makes in relation to where to feed, the length of time it will spend fishing in one place, and decisions on how far it is ‘prepared’ to fly when switching to a new foraging site. It is therefore critical to understand both how much energy Cormorants require and how this energy is acquired.

In the past, Cormorants were accused of devouring huge amounts of fish valuable to humans, and several early studies estimated that they consumed more

Table 4.3 Estimated daily food intake (DFI, g/day) for both European races of Great Cormorant (different sexes, ages, and activities) and mean body mass values (and methods) from which these have been derived (from Carss *et al.* 1997). These figures have then been used to determine the estimated DFI as a percentage of the mean body mass.

| Race | Age, (season or activity) | Mean body mass (g) | Estimated daily food intake g/day | Estimated DFI as percentage of mean body mass | Method used |
|-----------------|-------------------------------|--------------------|-----------------------------------|-----------------------------------------------|-------------|
| <i>sinensis</i> | Adult (wintering) | 2,275 | 707 | 31% | 31% |
| <i>sinensis</i> | Immature (wintering) | 2,079 | 662 | 32% | 32% |
| <i>sinensis</i> | Adult (incubating) | 2,230 | 251 | 11% | 11% |
| <i>sinensis</i> | Adult (rearing small chicks) | 2,230 | 334 | 15% | 15% |
| <i>sinensis</i> | Adult (rearing downy chicks) | 2,230 | 621 | 28% | 28% |
| <i>sinensis</i> | Adult (unknown) | 1,915 | 502 | 26% | 26% |
| <i>sinensis</i> | Adult (wintering) | 2,122 | 522 | 25% | 25% |
| <i>carbo</i> | Adult (wintering) | 2,901 | 843 | 29% | 29% |
| <i>carbo</i> | Immature (wintering) | 2,675 | 790 | 30% | 30% |
| <i>carbo</i> | Adult males (chick-rearing) | 2,870 | 890 | 31% | 31% |
| <i>carbo</i> | Adult females (chick-rearing) | 2,870 | 800 | 28% | 28% |

than the equivalent of their own body mass in fish per day (e.g. 187% of body mass; Black 1964). However, more recent studies have shown that a Cormorant's daily food requirements, even during energetically challenging periods (e.g. during chick rearing or during winter at low ambient temperatures), are considerably lower than this. In fact, several studies (e.g. Grémillet *et al.* 2003) reported that daily food requirements of Great Cormorants are actually no different from several species of seabirds of similar body mass. Carss *et al.*

(1997, see Table 4.3 above) tabulated current (at that time) estimates of daily food intake for individuals of both *carbo* and *sinensis* races Great Cormorants, based on predictive equations, time budgets (using a variety of techniques, assumptions and estimates) and for a number of situations (times of year).

Overall (see Table 4.3), for both these races of Great Cormorant there is variation between the studies in both the body mass (over 300 g difference within *sinensis*, over 200 g within *carbo*)

and the estimated daily food intake (differences of almost 400 g/day for *sinensis* and 100 g/day for *carbo*). Obviously a considerable amount of this difference in estimated daily food intake will be due to the different energy (and hence food) demands on the birds engaged in different activities. Taking DFI as a percentage of body mass, estimates vary but are commonly around 25–30% for *sinensis* and 30% for *carbo*. Further estimates of daily energy expenditure and daily food intake are given in section 4.7.5 (Table 4.5).

One possible way to investigate the food consumption of animals in the wild is to study their energetic requirements. The energetic costs for an animal to live throughout a day following its normal routine are defined as its daily energy expenditure (DEE). Once an estimate of DEE is established, this can be converted to an estimate of daily food intake if information on diet, its energy density, and the digestive efficiency of the consumer are available. Here we will briefly discuss what determines Cormorant energy requirements, the factors affecting them, and the methods available to estimate energy requirements and, ultimately, food consumption. As Carss *et al.* (1997: 214) emphasise 'pellets, the stomach contents of shot birds, and regurgitations cannot be used to derive good estimates of DFI because of the associated biases in estimating diet' (discussed in section 4.3). Similarly, estimates of DFI derived from feeding captive Cormorants or from food requirements of well-grown chicks almost invariably underestimate DFI as the flying

and/or swimming components of the bird's energy budget are excluded in such calculations. The solution to these problems is thus to base estimates of DFI on considerations of the energy requirements of wild birds.

4.7.2 Metabolic rate and its modifiers

The energy contained in the food that animals ingest becomes available during digestion through the stepwise transformation of larger molecules (into ultimately CO₂ and water) in a process called oxidation. The sum of all chemical reactions that occur in an organism over a specific period is defined as its 'metabolic rate'. Various components contribute to the overall metabolic rate of an animal. The minimal rate of energy expenditure in an endotherm (essentially, 'warm-blooded' birds and mammals) under defined conditions is called basal metabolic rate (BMR) and only varies with time of day or season. Apart from these basal requirements, adult birds also spend energy for thermoregulation, digestion, moult, and locomotion (e.g. flying, diving). The daily energy requirement of an animal will thus depend on which activities it engages in and for how long. It furthermore depends on the energetic costs associated with these activities and on a multitude of environmental factors that will modify these costs (e.g. climatic conditions such as air and water temperatures, solar radiation, and wind exposure). For Cormorants, flying and diving are the most costly activities and it is not surprising that these activities

usually make up a relatively small portion of their daily time-activity budget (see Grémillet *et al.* 2003 and Grémillet *et al.* 2005b).

As pursuit divers, Cormorants submerge to depth, where they will search, pursue and ultimately capture their prey. Water temperature will therefore be an important factor to consider when trying to estimate dive costs in these birds (Enstipp *et al.* 2005, Enstipp *et al.* 2006a). The depth to which birds descend will also modify dive costs. Buoyancy in Cormorants is lower than that of other aquatic birds because of their partially wettable plumage (Lovvorn & Jones 1991, Grémillet *et al.* 2005a). This reduces the amount of work that birds have to do in order to counteract their buoyancy during diving, decreasing overall locomotor costs considerably. With increasing water pressure, the birds' plumage air layer becomes compressed as it dives deeper, reducing buoyancy work even further. However, birds also rely on the air layer trapped within their plumage for insulation, so that heat loss to the environment at depth will be greatly increased. Enstipp *et al.* (2006a) found that dive costs in Double-crested Cormorants (*Phalacrocorax auritus*) when diving vertically to

10 m were on average 22% greater than when birds performed shallow horizontal dives (at depths of around 1 m).

The daily energy expenditure of Cormorants might vary to some degree from day to day, depending on a multitude of biotic and abiotic factors that should be taken into consideration. Most importantly, however, it will vary during the annual cycle of an animal. For example, energy expenditure might be greatly increased during the breeding season, especially during chick-rearing, when birds have to catch sufficient fish not only for themselves but also for their chicks. Accordingly, birds will increase their foraging effort (e.g. increase flight times, dive bout duration and/or dive depth), which will lead to a greater energetic demand and, therefore, food intake. Another potentially challenging period for Cormorants is the winter, where low air and water temperatures might greatly increase thermoregulatory costs. Seasonal or long-term changes in prey abundance (perhaps due to climatic fluctuations or overfishing for example) might also force Cormorants to increase their foraging effort. Indeed, Enstipp *et al.* (2007) showed that foraging success of Double-crested

Table 4.4 Activity specific energy expenditures (W kg⁻¹) for *Phalacrocorax carbo carbo* (mean body mass: 3.2 kg).

NOTES: ^a modified from measured value reported by Storch *et al.* (1999), ^b estimated from measurements in double-crested Cormorants (*P. auritus*) (Enstipp *et al.* 2006a), ^c modified from measured value reported by Grémillet *et al.* (2003). ^d from Grémillet *et al.* (2003), who used the aerodynamic model of Pennycuik (1989) to estimate flight costs. Water temperature during measurements in water was 13°C. Air temperatures during measurements were within the thermoneutral zone (TNZ) of Cormorants.

| Rest (day) ^a | Rest (night) ^a | Rest (on water) ^b | Diving (1m) ^c | Diving (10m) ^b | Flying ^d |
|-------------------------|---------------------------|------------------------------|--------------------------|---------------------------|---------------------|
| 4.4 | 3.7 | 11.7 | 22.8 | 27.1 | 78.8 |

Cormorants depends greatly on prey density. Hence, birds might try to buffer any reduction in prey abundance by increasing their foraging effort in multiple ways, leading to an increase in both their DEE and DFI.

4.7.3 Activity-specific energetic costs of Great Cormorants

The estimated energetic costs associated with specific activities of Great Cormorants are listed in Table 4.4. All values were measured via respirometry with the exception of flight costs, which were estimated using the aerodynamic model of Pennycuik (1989). Respirometry uses measurements of the animal's respiratory exchange (oxygen uptake, CO₂ production) to calculate oxygen consumption rates. These can then be converted into metabolic rate when the substrate metabolised is known (lipid, protein, carbohydrate, as indicated by the respiratory exchange ratio or RER), using the appropriate energetic equivalents.

Cormorants also spend energy for activities not listed but their metabolic rate during these activities is usually just slightly higher than during the resting state and they typically account for only a minor portion of their daily energy requirements. The costs of wing-spreading, for example, were estimated by Grémillet *et al.* (2000) for Great Cormorants, based on respiratory measurements in Double-crested Cormorants (Hennemann, 1985). For a 3.2 kg Great Cormorant energy consumption during

wing-spreading was estimated at 6.2 W kg⁻¹.

When ingesting cold fish, birds will have to expend energy to warm the meal (in addition to the energy reported in the table for 'resting') so that further digestion can take place effectively (Grémillet & Schmid, 1993). During digestion, the bird's metabolic rate will be elevated due to the metabolic processes of digestion, assimilation, and nutrient interconversion. As these processes are accompanied by the release of heat, this phenomenon has become known as the heat increment of feeding (HIF). The magnitude and duration of the HIF depend on meal size and food type, a diet rich in protein and a large meal size having the greatest effect. For Double-crested Cormorants, Enstipp *et al.* (2008) found that the energetic costs attributable to the digestion of a single 100g Herring *Clupea harengus* were 51 kJ (this includes the costs of heating the fish to body temperature), which represents about 5.5% of the gross-energy content of the fish and which was associated with an elevated metabolic rate for some 5–6 hours after feeding.

While the energetic costs associated with digestion should be incorporated into the daily energy budget, it is not clear yet, to what degree the heat released during digestion might potentially be used by birds to substitute for thermoregulatory costs. In other words, under some circumstances (i.e. at low ambient temperatures) birds might be able to use this excess heat generated during digestion for thermoregulation,

sparing them from having to spend additional energy to generate heat (i.e. through shivering or activity). In Double-crested Cormorants there is evidence for such a mechanism (Enstipp *et al.*, 2008).

4.7.4 Methods to estimate energy requirements

Estimating the energy requirements of free-ranging animals is a challenging task. Today, there are three different approaches to studying the field energetics of animals and each is discussed in detail below.

(1) Establishing a time-energy budget (TEB) by combining a detailed time-activity-budget (TAB) with laboratory measurements of activity-specific metabolic rates, while also taking into account a variety of biotic and abiotic factors (e.g. temperature) that influence the energy requirements. From the knowledge of how long an animal engages in each activity on a daily basis (and the energetic costs associated with each activity), daily energy expenditure can be calculated (Goldstein, 1988). It is obvious that the quality of a time-energy budget can only be as good as the components from which it was derived. In this context it should be noted that the accuracy of the time-activity budget (TAB) is crucial and will have the strongest impact on the overall estimate of energy requirements.

A variety of techniques can be combined to establish a detailed TAB. In the past researchers often used a combination of direct observation and bird instrumentation (e.g. radiotelemetry) to distinguish

Table 4.5 Estimates of DEE and DFI in Cormorants. All DEE and DFI values during the breeding season do not take into account chick energy requirements.

| Species | Body mass (kg) | Location | Period | Method | DEE (kJ day ⁻¹) | Conversion efficiency (%) | Fish energy density (kJ g ⁻¹ wet mass) | DFI (g fish day ⁻¹) and as % of body mass | Reference |
|--------------------------------|----------------|-----------|---------------|--------|-----------------------------|---------------------------|---------------------------------------------------|-------------------------------------------------------|---------------------------------|
| <i>P.c. sinensis</i> | 2.23 | Germany | Incubation | TEB | 760 | 77.0 | 4.0 | 247 (11%) | Grémillet <i>et al.</i> (1995) |
| <i>P.c. sinensis</i> | 2.23 | Germany | Chick-rearing | TEB | 997 | 77.0 | 4.0 | 324 (14%) | Grémillet <i>et al.</i> (1995) |
| <i>P.c. sinensis</i> | 2.12 | Germany | Winter | DLW | 2094 | 77.65 | 5.0 | 539 (25%) | Keller & Visser (1999) |
| <i>P.c. carbo</i> | 3.2 | France | Incubation | TEB | 2131 | 77.0 | 4.0 | 692 (22%) | Grémillet <i>et al.</i> (2000) |
| <i>P.c. carbo</i> | 2.3 | France | Incubation | TEB | 1532 | 77.0 | 4.0 | 497 (22%) | Grémillet <i>et al.</i> (2000) |
| <i>P.c. carbo</i> | 3.2 | France | Chick-rearing | TEB | 2500 | 77.0 | 4.0 | 812 (25%) | Grémillet <i>et al.</i> (2000) |
| <i>P.c. carbo</i> | 2.3 | France | Chick-rearing | TEB | 1797 | 77.0 | 4.0 | 583 (25%) | Grémillet <i>et al.</i> (2000) |
| <i>P.c. carbo</i> | 3.2 | Scotland | Winter | TEB | 2779 | 77.6 | 5.33 | 672 (21%) | Grémillet <i>et al.</i> (2003) |
| <i>P.c. carbo</i> | 3.5 | Greenland | Winter | TEB | 3632 | 77.6 | 4.0 | 1170 (33%) | Grémillet <i>et al.</i> (2005b) |
| Other Cormorant species | | | | | | | | | |
| <i>P. aristotelis</i> | 1.78 | Scotland | Chick-rearing | TEB | 2249 | 81.0 | 5.4 | 514 (29%) | Enstipp <i>et al.</i> (2006b) |

between time spent at the colony and that spent foraging. With recent technological developments a number of miniaturized electronic devices are now available that can be attached to Cormorants and which enable us to accurately record the amount of time that birds engage in a range of activities. For example, Daunt and colleagues used a combination of compass loggers and time-depth-recorders in European Shags *Phalacrocorax aristotelis* to distinguish between phases of (i) rest on land or at sea from (ii) flight and (iii) diving (Enstipp *et al.*, 2006b). One general problem here - and one which concerns all three methods - is the necessity of capturing and recapturing individual birds. This can often

be a challenging problem and explains the general bias in field studies towards the breeding season when it is generally easiest to catch and re-catch birds as they are highly faithful to their nest sites and young and unlikely to abandon them. In this context it is noteworthy that three studies have actually estimated DEE of Great Cormorants during the winter period (Keller & Visser, 1999; Grémillet *et al.*, 2003, and Grémillet *et al.*, 2005b). These studies are especially important as many of the conflicts with Cormorants, and hence considerable demand for rigorous estimates of daily energy expenditure and daily food intake, occur during the winter (i.e. non-breeding period) in many parts

of Europe (Carss 2002, Carss & Marzano 2003).

A further problem with time-energy budget calculations is that the separation of the various activities and their associated energetic costs overlooks the fact that they are not necessarily independent from each other. Many components of the TEB might interact and so modify the resulting total energy expenditure of an animal. For example, heat generated through physical or physiological (e.g. digestive) activity might be used for thermoregulation (i.e. 'keeping warm'), sparing birds from having to spend additional energy to generate heat. This could be an important factor during the winter,

when ambient temperatures in most cases will be below the lower critical temperature of Cormorants. At these times birds might have to spend significant additional energy for thermoregulation but this is usually not accounted for in time-energy budget calculations. Hence, energetic measurements that investigate the interaction of the various biotic and abiotic factors during certain activities are of great importance and some investigations have been conducted in Cormorants. For example, Enstipp *et al.* (2005) and Enstipp *et al.* (2006a) investigated the effects of a number of factors (air and water temperature, dive depth, nutritional state) on the diving energetics of European Shags and Double-crested Cormorants. A further area of great importance is the energetic costs associated with flight. Estimates in time-energy budget calculations are usually based on the aerodynamic model of Pennycuik (1989). However, this model produces extremely high flight costs for Cormorants and there is a clear need for further research, perhaps using doubly-labelled water (see below), to validate these predictions or produce revised estimates for the energetic costs of flight.

(2) The doubly-labelled water (DLW) method (Lifson *et al.* 1955) estimates the rate of CO₂ production from the difference in the rate of loss of so-called ‘labelled hydrogen’ (²H or ³H) and oxygen (¹⁸O) from the animal’s body. CO₂ production can then be converted to a measure of daily energy expenditure through a well-known ‘respiratory quotient’ (see Carss *et al.*, 1997 for further details). It is the method

most commonly used today for measuring daily energy expenditure in seabirds and has also been used for Great Cormorants (Keller & Visser 1999). However, there are a number of important assumptions and requirements for this method to produce a reliable estimate of daily energy expenditure (see Speakman 1997). There are also some drawbacks. A major disadvantage is that accuracy of individual measurements is so low that it can not be reliably used to estimate the energy demands of an individual bird. The reasons behind this remain, as Butler *et al.* (2004) put it, ‘obscure’ and DLW studies therefore require relatively large sample sizes (e.g. 9–10 individuals). Another big drawback with this method is that it only provides a mean value of energy expenditure over the entire study period. In other words, it is not possible to assess the costs of specific activities. Some studies have tried to overcome this last problem by simultaneously deploying activity recorders to gather time-activity data, which then enable back-calculation of specific activity costs (e.g. flight). However, the latter approach has met with criticism (see Wilson & Culik 1993).

(3) The heart rate method (Butler 1993) exploits the physiological relationship between heart rate (f_H) and oxygen consumption rate (V_{O_2}) and requires calibration of both variables against each other under controlled conditions. Oxygen consumption rate can then be estimated from heart rate recorded in free ranging animals (for a comparison of DLW and heart rate methods see Butler *et al.* 2004). While this method requires surgical

implantation it has great potential for the future, especially since further miniaturization of memory chips will allow data collection over extended periods. This is particularly important in the context of DEE variations throughout the annual cycle of Cormorants. Given the logistic constraints, most field studies on seabird energetics have been carried out during the breeding season, an energetically challenging time. Consequently, DEE estimates are biased and might (or might not) be lower outside the breeding season.

With the development of miniaturized, implantable data-loggers, the recording of physiologically relevant variables (e.g. heart rate) for extended periods (currently up to one year, see Grémillet *et al.*, 2005b) has become possible. Heart rate, when properly calibrated against oxygen consumption (see Butler 1993 and Butler *et al.*, 2004 for details), might serve as a proxy for energy expenditure. Hence, with the deployment of this technique in the future, might allow researchers to gain a better understanding of how energy expenditure varies throughout the annual cycle of Cormorants.

4.7.5 Daily energy expenditure (DEE) in Great Cormorants

For Great Cormorants, only the first two methods described above have been used to estimate daily energy expenditure. Results from these studies are compiled (Table 4.5) and it is clear that estimates of DEE vary considerably with location and period of the study. The high energetic expenditure

during chick-rearing most likely reflects increased activity as a consequence of having to deliver sufficient food for the chicks. High energy expenditures during the winter are probably a consequence of low ambient temperatures and the associated increased energy required to ‘keep warm’. The study by Grémillet *et al.* (2005b) represents an extreme case, where birds winter at the limit of their northern distribution range, near the Arctic Circle. Here, Great Cormorants encounter air temperatures well below zero (down to -30°C) and water temperatures as low as -1°C , while also increasing their dive depth throughout the winter (mean dive depth = 18 m, with some dives exceeding 40 m).

4.7.6 Converting daily energy expenditure (DEE) to daily food intake (DFI)

If we want to convert the estimate of energy expenditure into fish mass required to satisfy these energetic needs, we need detailed information on three things.

1. The diet composition, that is which fish species are taken and in what proportions? (see sections 4.3.2 and 4.4.3);
2. the ‘energetic density’ of the fish species consumed. In other words, the calorific content of the prey, ‘oily’ fish such as Herring and Eel *Anguilla anguilla* being more energy-rich than Cod *Gadus morhua* or flatfishes (e.g. Pleuronectidae) for instance, and;
3. the efficiency with which Cormorants convert the ingested energy contained in the fish.

Diet information can be obtained in numerous ways, through direct observation (section 4.2), pellet analysis (section 4.3) or from analysis of stomach contents or regurgitations (sections 4.4 and 4.5). The energetic density of fish taken should ideally be measured directly via bomb calorimetry. If this is difficult, values might alternatively be found in the literature. However, one should be aware that energy density varies considerably throughout the annual cycle of fish and might also differ between geographic regions (see for example Hislop *et al.* 1991) and this can potentially introduce a big error into the DFI estimate.

From the knowledge of diet composition and its energetic density, a ‘composite energy density’ value can be calculated and DEE can be converted to DFI. However, not all the energy contained in a fish can be converted and retained by the bird swallowing and digesting the fish. Hence, we also need to know what proportion of the total energy held within a fish can be retained by a Cormorant. This has to be accounted for in the DFI estimate and will consequently increase our original estimate. For Great Cormorants no estimates of energy conversion efficiency exist. However, Brugger (1993) investigated the ‘digestibility’ of three fish species by Double-crested Cormorants. The proportions of total energy within fish that were actually obtained by the birds — the so-called ‘nitrogen corrected metabolizable energy coefficients’ were about 75% for Bluegill (*Lepomis macrochirus*), about 78% for Gizzard Shad (*Dorosoma cepedianum*), and 79%

for Channel Catfish (*Ictalurus punctatus*). In other words, the birds only ‘absorbed’ about 75–80% of the actual energy content of the fish that they ate, and this ‘absorption rate’ clearly differed for different fish species.

4.7.7 Models to estimate daily energy expenditure (DEE) and daily food intake (DFI) in Cormorants

Grémillet *et al.* (2003) established a computer model (Excel spreadsheet) that can be used to calculate the DEE and DFI of Great Cormorants from detailed time-activity data. It combines time-activity data (which can be changed according to situation) with activity-specific metabolic rates (representing the state of knowledge in 2003). It is based on observations of Great Cormorants wintering in Scotland and incorporates the energetic costs associated with resting, flight, diving, and wing-spreading. It also takes into account a number of factors influencing dive costs, such as water temperature, dive depth, and dive-pause ratio.

Enstipp *et al.* (2006b) used a similar model to establish a time-energy budget and to estimate daily energy expenditure and daily food intake for European Shags during chick-rearing in Scotland. While these models are quite useful, they can only be as good as their input data and even then important assumptions and restrictions should not be overlooked. One should not be overwhelmed by the apparent ease with which parameters can be calculated with these models and they should also be improved

as further knowledge becomes available. For example, while the effect of depth on the energetic costs of diving is incorporated in the model by Grémillet *et al.* (2003), it is merely based on a physical model of heat loss. Enstipp *et al.* (2006a) measured the effect of dive depth on

Double-crested Cormorant dive costs via respirometry and found that the physical model used by Grémillet and colleagues greatly overestimates this effect. Hence, new measurements should be incorporated into Grémillet *et al.*'s overall model, but this remains to be done.

More recently, Ridgway (2010) builds on many of the issues and studies described above and reviews estimates of daily energy expenditure and food intake in cormorants (*Phalacrocorax* spp.) and makes a number of recommendations for estimating DEE and DFI at the population level.

5 SEXING, AGEING AND MEASURING CORMORANTS

T Bregnballe, D N Carss, M van Eerden, S Newson, R Parz-Gollner and S van Rijn

5.1 Introduction

Cormorants are often casually referred to as ‘big black birds’. However, within well-defined ranges of course, they come in a variety of structural sizes and plumage colourations (see Figure 5.1 and others in this chapter). These differences in plumage colouration and structural size, if carefully and systematically recorded, can give valuable insight into several important aspects of the ecology of the species, for example in relation to timing and strategy of migration pattern and breeding. Plumage colouration can be used to determine the age of birds — at least categorising them as ‘juvenile’, ‘immature’ or ‘adult’ (i.e. sexually mature). This can be used (in conjunction with roost counts, see section 3.3) to record the proportional (i.e. adult:immature) age-composition of birds at roosts for instance or the use of particular roosting or foraging sites by different age-classes of birds. Structural size of birds can help to determine the sexes of the birds in the field. This knowledge, also from dissected individuals also contributes to a better understanding of timing of migration and strategies of birds.

Sexing and ageing Cormorants can be performed on live birds, based on characteristics relating to the appearance of the bird (Millington 2005, Newson *et al.* 2004). Breeding birds can also often be sexed based on observations of behaviour (displaying and copulations). With some experience the sex of a bird can be estimated based on its general structure, for example the size and appearance of the bill and head. Measuring birds is most often carried out when ringing nestlings but also when birds are caught or shot under licence.

Observations of ringed birds (of known age) give the opportunity to check if a field estimate of age based upon plumage characteristics is correct. Colour-ringed birds of known sex (based on behaviour in the breeding season) make it possible to recognise sexes based on a comparison of structural size with other birds.

Carcasses can be studied by describing the plumage and by an examination of the bird’s reproductive organs through dissection. Analysing carcasses gives the opportunity to relate structural size to the sex of individuals. Observations of ringed birds (of



Figure 5.1 Two ring recoveries showing differences in body size and plumage characteristics (birds shot in Austria January 2006). Left: (No. 382) ringed in Denmark, adult, breeding plumage, male, age 3 years and 8 months. Right: (No. 379) ringed in Finland, male, immature, age 1 year and 8 months.

Photo courtesy of R Parz Gollner.

known age) give the opportunity to check if an informed guess of age-related to plumage is correct.

When analysing carcasses, sex and age-related differences in plumage colouration of birds also allow researchers the opportunity

to examine Cormorant diet (see chapter 3) in relation to different sex and age classes. Plumage colouration, particularly the development of breeding plumage, can also be used to compare the diet of breeding birds with those of non-breeders. Almost exclusively, these measurements and observations are restricted to dead birds but they can be used to help to interpret dietary information obtained in the field.

In terms of 'size', the careful standardised measurement of various features of a Cormorant's body such as weight ('mass'), wing-length, and bill shape and size can help to determine sex of birds. Females are generally smaller than males as shown by discriminant analyses discussed later on in this chapter.

Differences in structural size between males and females can for example affect individual hunting performance (see Koffijberg & van Eerden 1995). For example, a sex-specific foraging skill could affect foraging success and/or prey choice

of individual birds. This ecological segregation might also affect the behaviour of males and females within flocks of social fishing individuals as well as the distribution of both sexes in wintering areas (van Eerden & Munsterman 1986).

By observation from a combination of body size, bill shape and structure as well as the shape of the forehead, it may be possible to estimate the sex of individual birds in the field. Experienced and trained observers may thus estimate sex ratio in various flocks. Any differences in the use of habitat between males and females and between adults and immature birds is likely to have an ecological explanation, which will contribute to our understanding of the temporal and spatial use of different habitats across the species' range (van Eerden & Munsterman 1995).

Measurements of various features of the Cormorant's head can provide useful information on the racial identity of the individual (see

4.5). Whilst there is still much to learn about the genetics of Great Cormorants across the geographic range of the species, biometric measurements allow the majority of *P. c. carbo* and *P. c. sinensis* individuals to be correctly assigned to the level of subspecies. The angle of the gular pouch is a good measure to separate the subspecies (Newson *et al.* 2004).

Measurements from Cormorant chicks also provide useful information (see 5.6 and Figure 3.12). Thus, biometrics of nestlings can be used to estimate the age (in days) by taking the wing length of chicks to reconstruct hatch and egg laying dates based on the growth curve of the wings. Such information is important to understand the relationship between the timing of breeding and environmental conditions in the field, such as food abundance and weather conditions for example. Additionally these measurements can be used to determine the body condition of chicks by calculating



Figure 5.2 Adult Cormorant (No.432), female, ventral side showing complete black breast and belly, no breeding plumage; net weight 1,700g; ringed 7.6.2002 in Sweden, shot 10.1.2006 in Austria (3 years, 7 months).

Photo courtesy of R Parz Gollner.

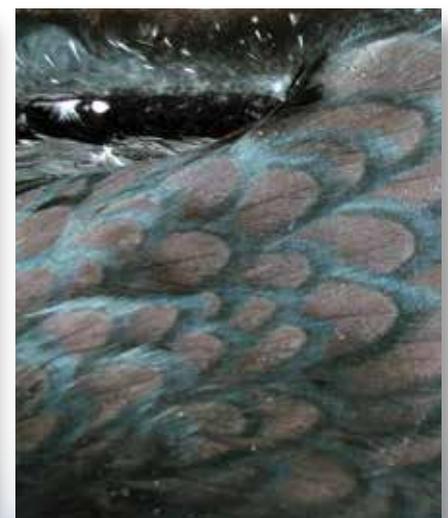


Figure 5.3 Adult Cormorant, dorsal view, note the bronzy scapular feathers with black margins.

Photo courtesy of R Parz Gollner.

its relative mass (referring to age), which offers the opportunity of relating this to environmental conditions and survival.

5.2 Plumage colouration — age determination

Only full-grown Cormorants appear to be completely ‘black’ but see Figures 5.2 and 5.3. Adult (pre-) breeding birds have an overall ‘black’ plumage, but this is glossed purplish or iridescent green with bronzy sheen on scapulars, tertials and upperwing coverts.

Further characteristics of the adult breeding plumage (in both sexes) are a ‘crest’ of long, white filoplumes extending down the back of the neck giving a variably ‘hoary’ appearance, and a large white patch of filamentous feathers on each flank. Birds have conspicuous yellow gular skin with a white border, a small orange patch below an emerald green eye with an orbital ring of grey, yellow or black. The lores (the space between the eye and the bill in birds) is yellow to orange, the bill is dark, becoming yellower at base of mandibles, the legs and feet are black. Mature plumage is acquired by year 3 or 4 and third-winter birds resemble post-breeding adults but still have a mottled belly (see Nelson 2005).

Unlike adult birds, immature individuals have highly variable breast plumage. This ranges from an almost completely white breast, through a white breast speckled with ‘black’, to an almost black breast speckled with white. There appears to be little, or no, relationship between the degree of ‘black’ on the breast and the age of these immature birds. The



Figure 5.4 (top) Immature Cormorant (No. 399), female, 1,680g, (shot in Austria, winter 05/06). Photo courtesy of R Parz Gollner.

Figure 5.5 (above) Immature Cormorant (No. 447), female, 2,034g, (shot in Austria, winter 05/06). Photo courtesy of R Parz Gollner.



Figure 5.6a–d Immature Cormorants, various extent and pattern of white and dark on underparts. Photos courtesy of R Parz Gollner.



Figure 5.7 Wing of first-year Cormorant (*top*) and adult bird (*above*). Photo courtesy of T Bregnballe.

variation of types within a number of immature individuals is shown in Figures 5.4–5.6.

Other than the breast, the remainder of the feathers of immature birds are brownish rather than the dark black of adults. An example of this difference in the wing feathers is shown in Figure 5.7.

During the breeding season (and well before when still present in the wintering area) fine white head feathers ('filoplumes') appear on the adults and (later) on immature Cormorants. These become more prominent as the bird gets older. These diagnostic characteristics can help determine the proportion of sexually mature birds recorded in the field and at roosts. The development of it is related to the timing of breeding and can easily be scored in the field (see Figure 5.8). The breeding plumage is used

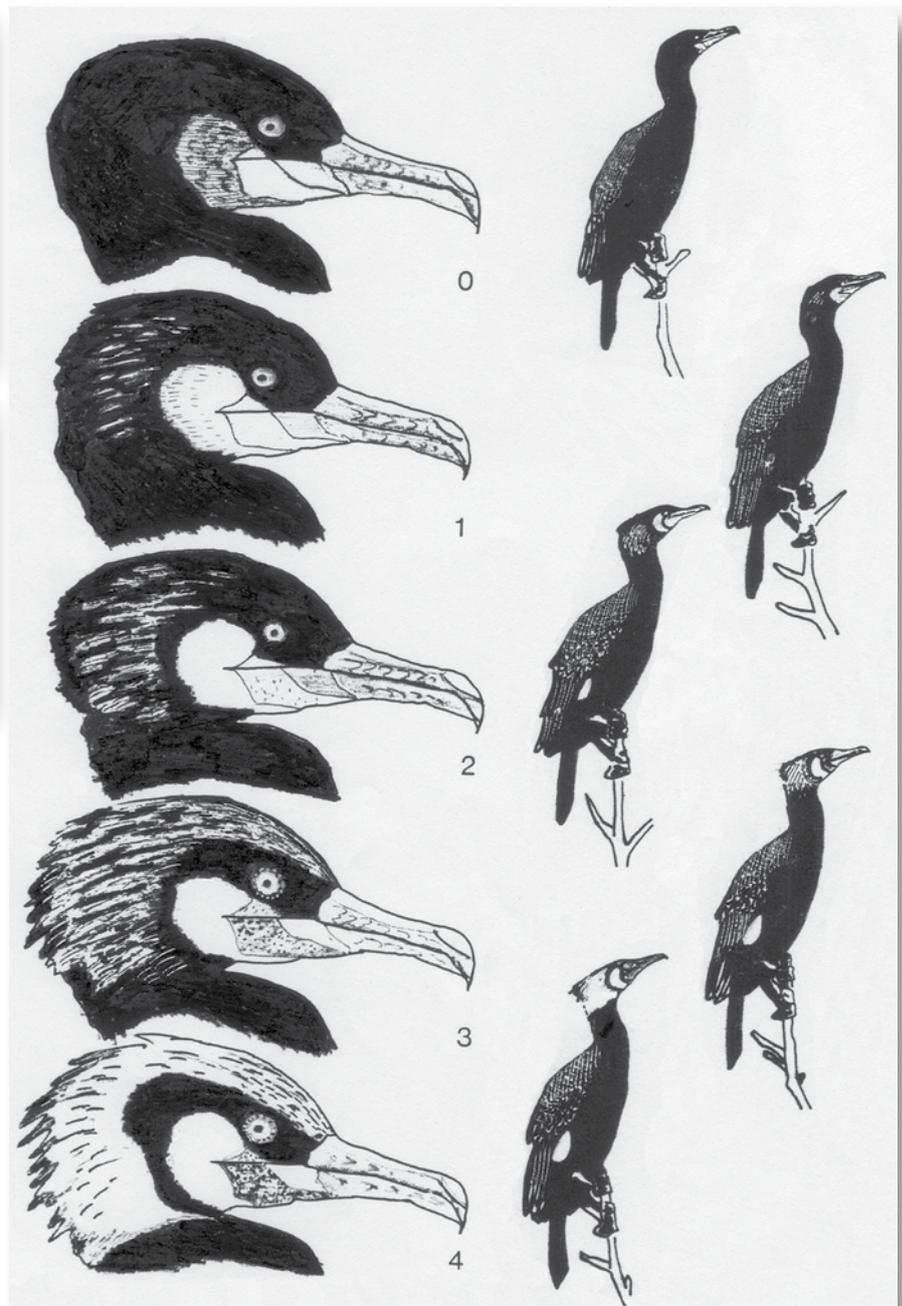


Figure 5.8 Index of cover of filoplumes of head (0 = no plumes, 4 = fully covered) and of the thigh patch (again scored 0–4). Drawing courtesy of M R van Eerden.

in display behaviour, to attract partners or impress neighbours. Observations of this index can help to describe breeding phenology and possible changes therein (geographical range, seasonal and annual variation). Related to the changing plumage, changes also occur in colour of the bare parts. The gular pouch becomes darker

and speckled, a small red dot appears at the lateral base of the bill and the bare parts around the eye get more colourful at the time of egg laying. All these characteristics fade away one after the other, starting during the first half of the incubation period. Of these the thigh patch remains visible the longest.

5.3 Body measurements — sex determination

Body length

Perhaps the most obvious measurement to take from a dead Cormorant is its length, total length being measured on the dorsal side from the tip of the bill to the end of the central tail feathers. This measurement is somewhat limited in accuracy, depending on how the dead bird was handled before being measured. If the bird was left hanging (see Figure 5.9) it will probably have been stretched. Care should be taken to avoid hanging or stretching the carcass.

In order to make measurements of the same dimensions comparable, researchers have standardised the exact positions from and to which they take specific measurements. Provided that the same measuring points are always used, the most useful and accurate measurements can be taken from head, wing, tail, leg ('tarsus') or breast-bone ('sternum').

A good set of scales or an automatic balance is needed to weigh birds (nearest gram) and a pair of Vernier callipers and a stopped rule to measure heads (legs or the sternum) and wing (tail), respectively. Measurements should be to the nearest 1 mm (for the head, tarsus, sternum, wing or tail).

Body Weight ('Mass') measurements

It is important to indicate whether the **gross** or the **net body mass** has been taken. Gross weight includes the oesophagus/stomach contents (food), whilst net weight can only be obtained by dissecting the bird. This distinction should always be noted, because the body mass recorded either with or without the



Figure 5.9 Many hunters store dead Cormorants by hanging them from the neck: this stretches body length and should be avoided.

Photo courtesy of T Bregnballe.

oesophagus/stomach contents can be more than the average difference in mass between males and females (see section 4.4). It should also be noted whether the bird was wet (i.e. taken from the water) or dry, when it was weighed.

Bill measurements

There are two standard bill measurements in use, both of which are taken with callipers. The



Figure 5.10a Yellow lines indicating the starting position on the upper mandible for measuring bill length (L, right bar) and bill depth (D, left bar). For measuring nestlings with un-feathered forehead see also Figure 5.17.

first, the **bill** (or 'culmen') **length** is taken from the feathers in the centre of the forehead at the base of the bill, to its tip (see Figure 5.10a, where the yellow line 'L' indicates the position of the starting point on the upper mandible).

The second is the **bill depth** (or height), a measurement taken vertically down on the base of the bill from the upper to the lower mandible. Note that there is a difference in taking bill depth measurements when handling birds of different age classes. Dealing with **nestlings**, this measure is taken at the base of the nostrils (see Figure 5.17). In the case of **fully-grown birds**, where no nostrils are visible on the culmen, the corresponding position to measure bill depth is taken vertically down along the line of the edge of the front feathers on

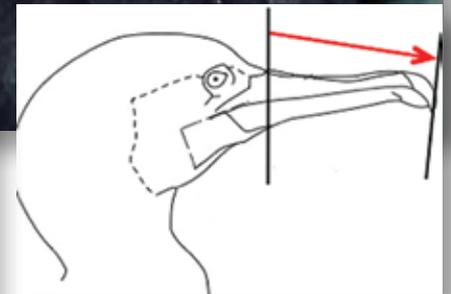
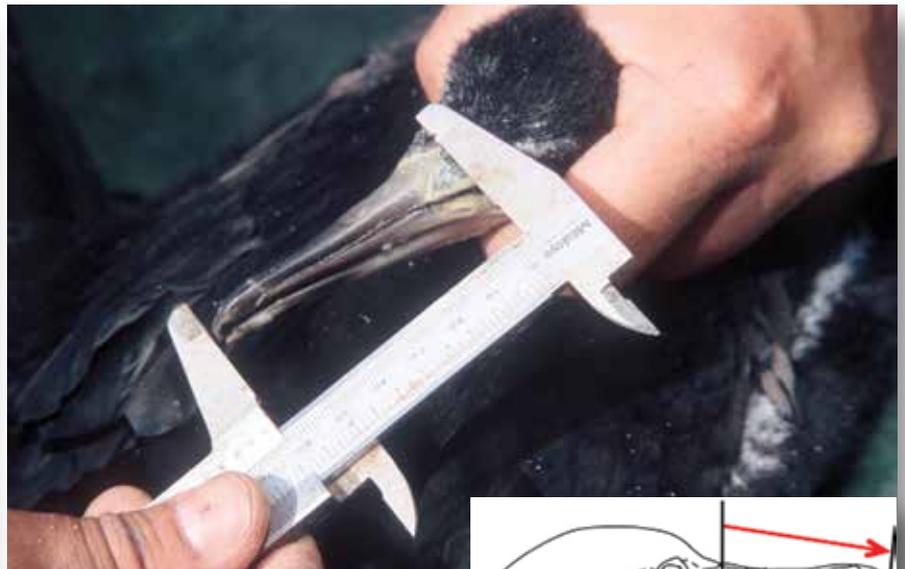


Figure 5.10b Lateral and dorsal views of measuring bill length in adult Cormorants.

Photo courtesy of S van Rijn.

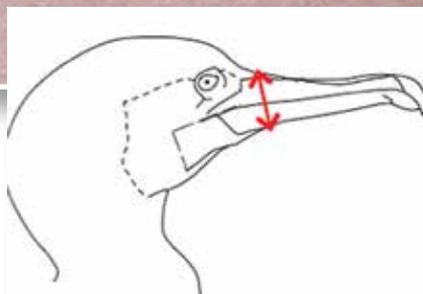
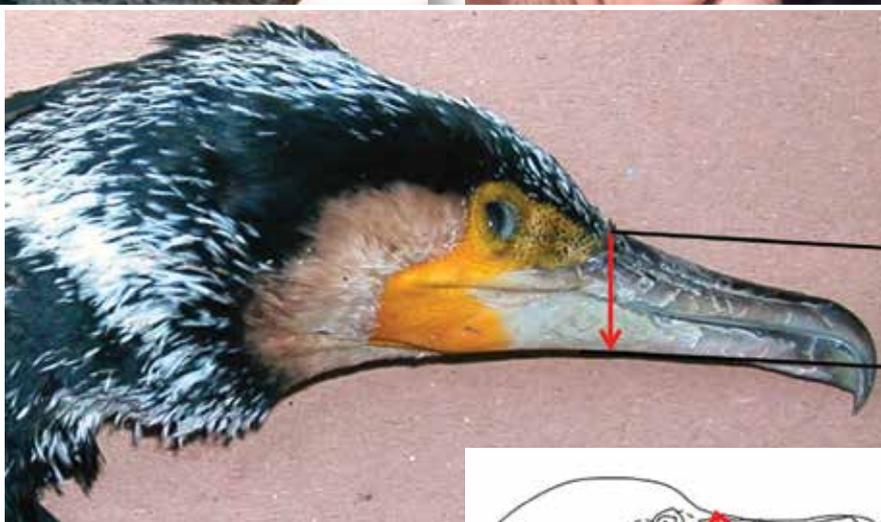


Figure 5.10c Lateral view of an adult Cormorant with the position for measuring bill depth indicated with red arrows. Photo courtesy of R Parz-Gollner.

the forehead as indicated with the line 'D' in Figure 5.10a.

Wing measurements

Standard wing length is measured with a stopped rule. The fold of the wing is placed against the stop and the primary feathers are straightened along the length of the rule. The wing length is measured to the extreme tip of the longest primary feather. This measurement is shown in Figure 5.11 and is also referred to as the 'maximum wing chord'.



Figure 5.11 Measuring wing length.

Photo courtesy of T Bregnballe.

5.4 Large Samples — sex and age discrimination

Here we discuss two studies that have had access to relatively large numbers of dead Cormorants. Both studies explore differences between both adult and immature birds of each sex. They show the value of such samples and the use to which the biometric measurements can be put.

Table 5.1 summarises four body measurements taken from a large sample of 'full grown' Cormorants shot during control actions in Austria (data collected between 1995/96–2006 courtesy of Rosemarie Parz-Gollner). Data from measurements of body mass (dry, net weight), bill (culmen) length, bill depth, and wing length are tabulated separately for

male and female birds categorised as either adult (AD) or immature (first winter) (IMM). Mean ('average') measurements are given as well as the minimum and maximum measurements recorded, and the total number (N) of birds measured in the sample. Measures for bill and wing lengths were taken as indicated in Figures 5.10a–c and 5.11.

Here, 'net weight' is obtained when the weight of food found in the stomach and oesophagus has been subtracted from the total (gross) weight of dead birds and total weight was taken before dissecting the carcasses. All birds in this sample have been dissected.

This comprehensive dataset shows clearly that female Cormorants are considerably smaller (by each of the four measurements taken here) than male birds. Furthermore, although this difference in size is also apparent for both adult and immature birds of each sex, there is very little size difference for either male or female birds between these two age-classes (Figure 5.12).

In these Figures (5.12a–c), the Box Plot graphics show lines at the top, bottom, and through the middle of the boxes which correspond to the 75th percentile (top quartile), 25th percentile (bottom quartile), and 50th percentile (the median). The horizontal 'whiskers' on the very bottom extend from the 10th percentile (bottom decile) and on the very top from the 90th percentile (top decile). A square symbol indicates the arithmetic mean for each sample.

Similar information was collected by Koffijberg & van Eerden (1995) from a sample of *sinensis*

Table 5.1 Body measurements of fully-grown Cormorants shot during control actions in Austria.

| | Males | | Females | |
|--------------------------------------------|-----------|-----------|-----------|-----------|
| | AD | IMM | AD | IMM |
| culmen (bill) length | | | | |
| Mean | 68.45 | 68.73 | 61.43 | 62.03 |
| Range | 62.8–77.8 | 60.8–77.3 | 55.1–68.9 | 55.8–68.3 |
| N | N = 96 | N = 142 | N = 57 | N = 59 |
| bill depth | | | | |
| Mean | 21.77 | 21.74 | 19.36 | 19.33 |
| Range | 19.7–24.7 | 17.3–26.6 | 17.4–21.2 | 17.6–22.3 |
| N | N = 95 | N = 141 | N = 57 | N = 59 |
| wing length | | | | |
| Mean | 359.12 | 359.59 | 338.23 | 338.36 |
| Range | 340–380 | 340–380 | 322–354 | 32–355 |
| N | N = 95 | N = 133 | N = 52 | N = 57 |
| body mass (dry plumage, net-weight) | | | | |
| Mean | 2440.53 | 2378.77 | 1983.74 | 1991.36 |
| Range | 1540–3440 | 1737–3230 | 1638–2580 | 1604–2623 |
| N | N = 124 | N = 175 | N = 69 | N = 75 |

Cormorants accidentally drowned in fishing gear. A series of measurements were taken from these birds which could be sexed on the basis of external examination and aged on the basis of their plumage characteristics (see section 5.2). Measurements taken were as follows:

- (i) Fresh body mass (dry plumage, nearest 1 g)
- (ii) Mass of fresh fish in the oesophagus (nearest 1 g)
- (iii) Body length (length of stretched body from tip of bill to tip of tail, nearest 1 cm)
- (iv) Wing length (nearest 1 mm)
- (v) Sternum length (nearest 0.1 mm)
- (vi) Bill length (nearest 0.1 mm)
- (vii) Bill depth (nearest 0.1 mm)

Discriminant analysis was used to examine which combinations of these measurements best predicted the sex of individual birds. The single measurement that best separated males and females was bill depth, according to the following equation:

$$D = 0.71 \times \text{Bill Depth} - 14.35$$

where a resulting D value greater than zero indicates a male bird and a D value less than zero indicates a female.

When tested, this measurement of bill depth correctly identified male and female birds in 85% of cases. Even higher proportions of individuals could be assigned correct sex when combinations of

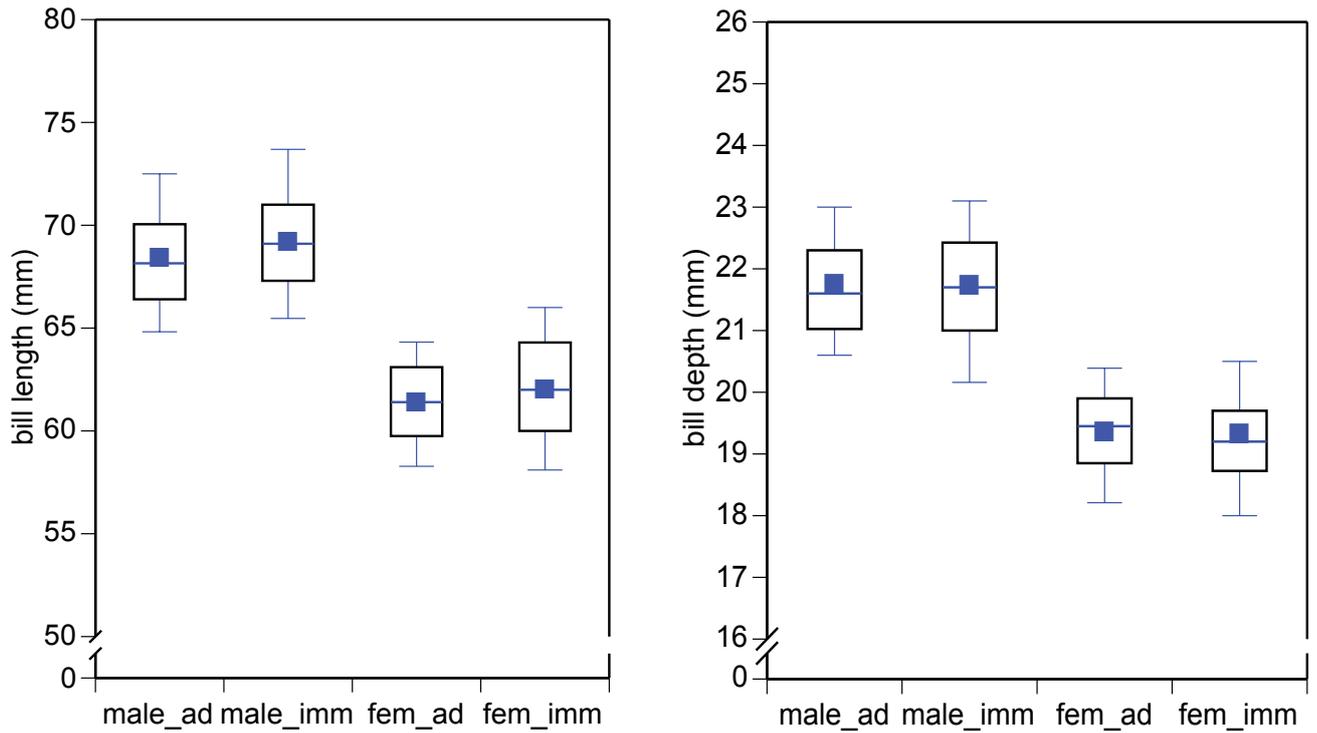


Figure 5.12a Sample size/box plot bill (culmen) length (*left*), bill depth (*right*); adult male — immature male, adult female — immature female. Measurements taken as indicated in Figure 5.10b and c.

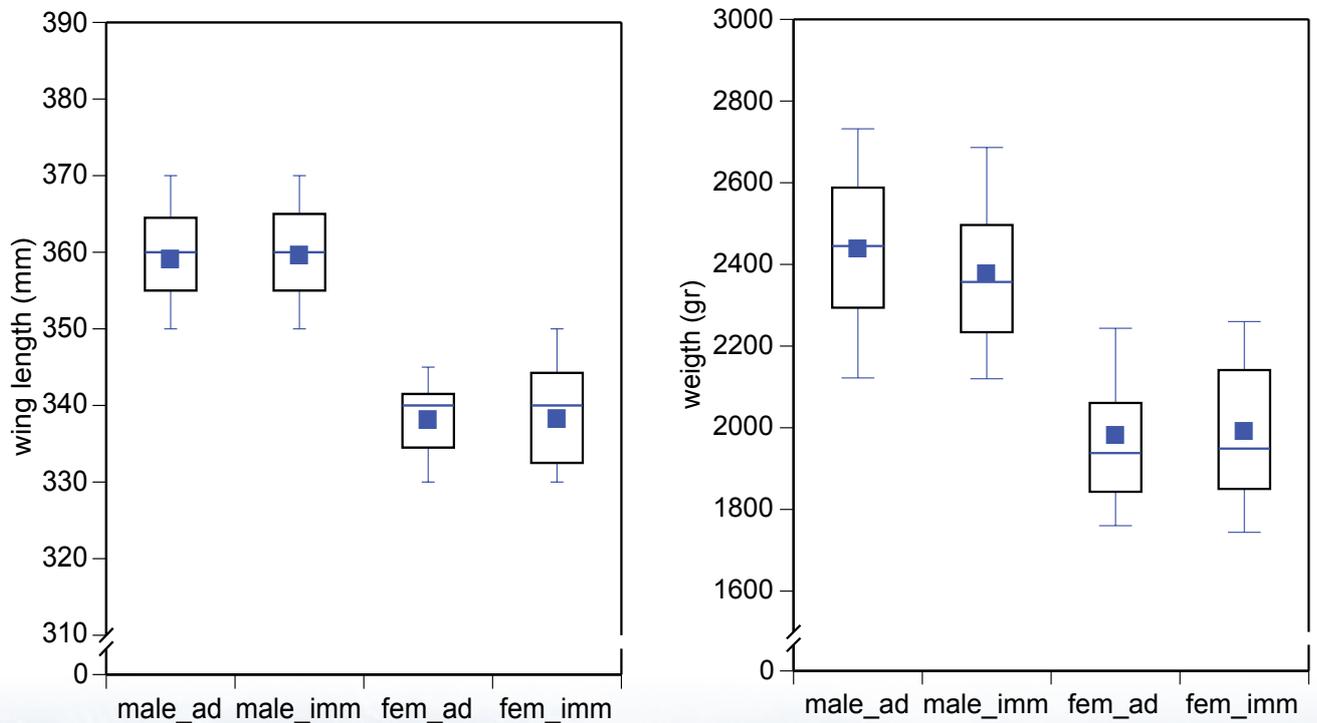


Figure 5.12b Sample size/box plot wing length; adult male — immature male, adult female — immature female.

Figure 5.12c Sample size/box plot body mass (dry plumage, net weight); adult male — immature male, adult female — immature female.



Figure 5.13 Immature female (*left*) and immature male (*right*) in the 1st winter — note the difference in bill shape between the sexes (see text for details). Photos courtesy of R Parz-Gollner.

body measurements were taken together. Furthermore, overall body measurements were better for assigning individuals as male birds — which are bigger than females and tend to vary in size less than the smaller females do (see Koffijberg & van Eerden 1995). As is usually the case, determining the sex of individuals is most difficult in young, immature birds where size is more variable than it is in fully-grown birds of either sex.

These authors took their analysis further by exploring whether there were any differences in the diet (using stomach contents, see section 4.4) of male or female birds. Although the species composition tended to be similar for both sexes, male

Cormorants did take significantly larger individual fish (of some species) than females did.

Finally, these authors also examined the general head/bill shape of male and female Cormorants (see their Figure 5) and showed that females had a ‘saddle-shaped and more slender bill’ than males, also that males had ‘a more massive, rather straight-edged bill’. Similarly, the ‘forehead of females often is more rounded compared to males’. A series of photographs of adult and immature Cormorants of both sexes is shown in Figures 5.13 and 5.14.

Other authors (e.g. van Eerden & Munsterman 1995) have gone on to use the combination of

body size, bill shape and forehead shape in the field with wild birds to determine different use of roosts and sex ration in several parts of the wintering range of the *sinensis* race. How these differences would apply to *carbo* birds is not known.

5.5 Racial identity (*carbo*, *sinensis*)

The use of biometric measurements for sub-specific identification in Great Cormorants was originally investigated using skins from birds of known sex and sub-species (Newson *et al.* 2004). This showed that the gular pouch (‘throat’) angle was a useful character for assigning individuals to subspecies. Where further measurements were



Figure 5.14 Left - immature male, 1st winter (ring recovery from Finland, 8 months old); Right — immature male, 2nd winter (ring recovery from Finland, 1 year and 8 months both birds shot in Austria). Note the massive, straight-edged or ‘conical’ shape of the bill and difference in plumage coloration of immature birds of known age. Photos courtesy of R Parz-Gollner.

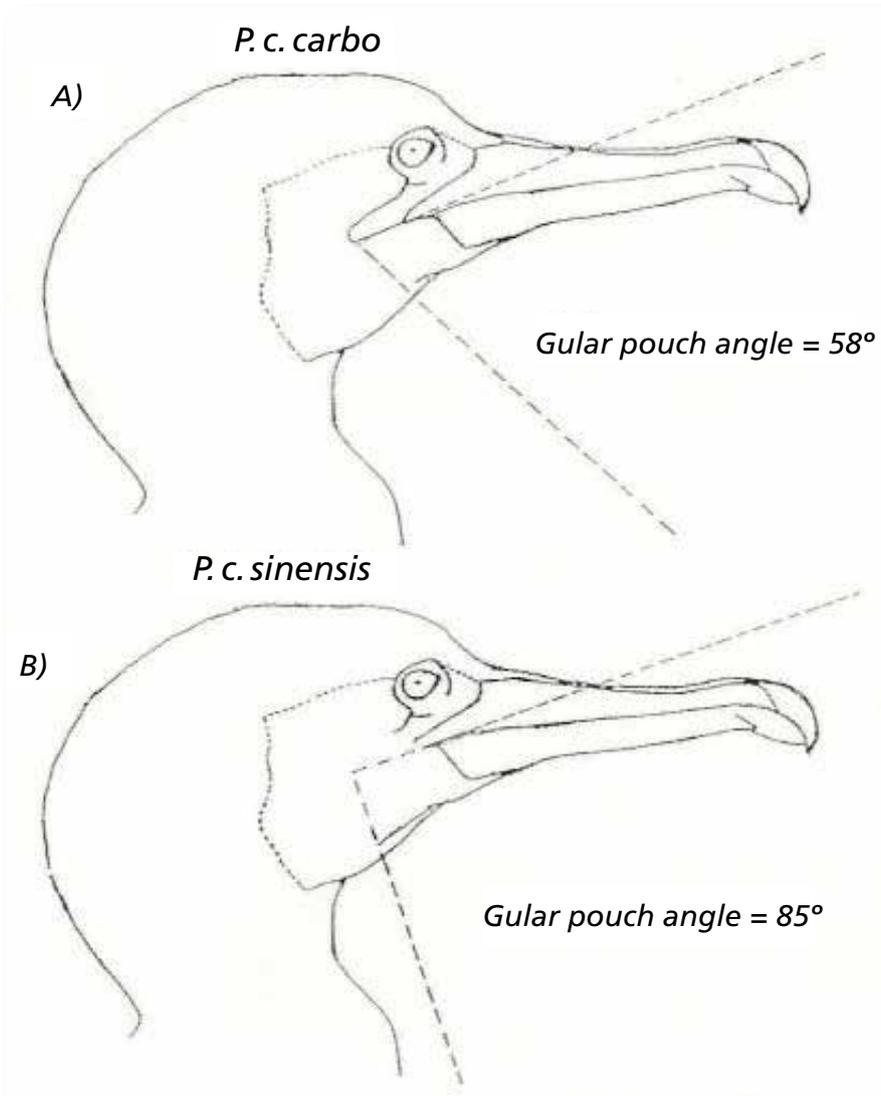


Figure 5.15 Gular pouch measurements for *carbo* (A) and *sinensis* (B) Cormorants — After Newson *et al.* 2004.

taken of bill depth and bill length, sex-specific formulae allowed the majority of individuals to be correctly assigned to either *carbo* or *sinensis* races. This character needs careful examination when applied in the field; if viewing angle (horizontal) and position of head (lateral side fully exposed to observer) are favourable, this character can successfully being applied in the field.

Thus it is possible to identify *carbo* and *sinensis* individuals of known sex, as follows. Bill length (BL) is measured from the tip of the bill to the feathers at the centre of the bill, bill depth (BD) at the narrowest point in the middle of the bill (see section 5.3). Gular pouch angle (GPA) is measured to the nearest 1° using a rotatable protractor (see Figure 5.15). It is important to note that the baseline from which the angle is measured is not the bill line, but the line from the gape outwards, chosen because it gives greatest reproducibility between measurements. On live or freshly dead specimens, it is important to note that the gular pouch can



Figure 5.16 Two individuals of nominate race *P.c.carbo*, shot winter 2001/02 in Austria. No. 219 (left) immature male, 2,921 g net weight, No. 226 (right) immature male, 3,140 g net weight. Photos courtesy of R Parz-Gollner.

be distorted to change its angle. With all measurements care should be taken to ensure that the pouch assumes a normal attitude by gently stroking it downwards before measurements are taken.

Males can be classified as *carbo* if the result of the following calculation is greater than 4.66583.

$$(0.92133 \times \text{BD in mm}) + (0.36504 \times \text{BL in mm}) - (0.50198 \times \text{GPA in degrees})$$

For example, a male Cormorant with measurements (BD 12.2 mm, BL 68.4 mm and GPA 82 degrees), gives a value of -4.9534, which is not greater than 4.66583 and so the individual is therefore categorised as belonging to the *sinensis* race. Similarly, females can be classified as *carbo* if the result of the following calculation is greater than 4.87236.

$$(0.87159 \times \text{BD}) + (0.56828 \times \text{BL}) + (-0.61081 \times \text{GPA})$$

5.6 Measurements from nestlings

Similar body measurements to those described earlier for adult and immature Cormorants can also be taken from younger birds in the nest (see Figures 3.12). Nestling biometrics can be used to determine age, growth rate, sex and condition of individual birds. On each nest visit, body mass and other parameters — wing length, bill length and bill depth of each nestling in a brood can be measured. Body mass can be determined to the nearest 5 g, using a Pesola spring balance. Wing length is measured with a stopped rule (see 5.3 the same for

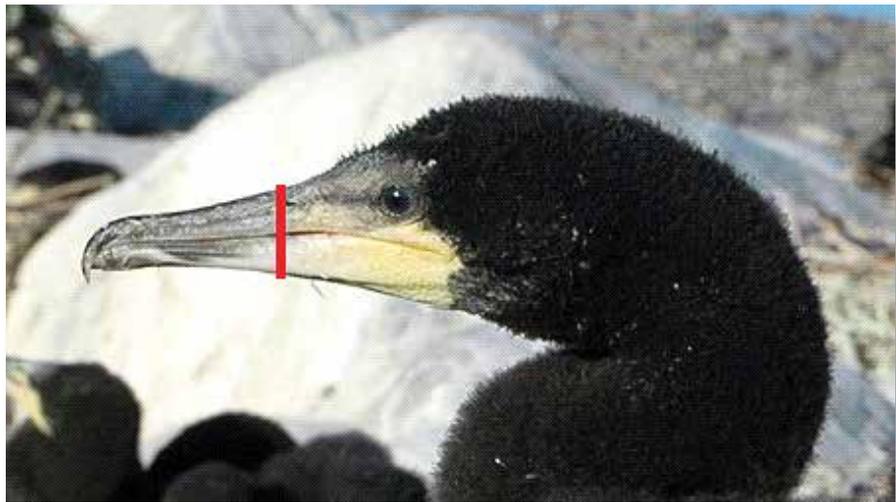


Figure 5.17 Nestling Cormorant, showing measurement of bill depth at base of nostrils (red line). This bird is likely to be a male, according to the unfeathered forehead at an age of about 20 days (Estonian colony, June 2007).

Photo courtesy of S van Rijn.

carcasses). The fold of the wing is placed against the stop and the primary feathers are straightened along the length of the rule. The wing length is measured to the extreme tip of the longest primary feather. This measurement is shown in Figure 5.11 and is also referred to as the ‘maximum wing chord’.

There are two standard bill measurements used by researchers (see section 5.3 and Table 5.1 for carcasses), both of which are taken with callipers. The first, the bill (or ‘culmen’) length is taken from the feathers in the centre of the forehead at the base of the bill, to its tip (see also Figures 5.10a and 5.10b). The second is the bill depth (or height), a measurement taken vertically down from the top edge of the upper mandible to the bottom edge of the lower mandible (Figures 5.10a and 5.10c). Measuring nestlings with an unfeathered forehead, the bill depth is taken at the base of the nostrils. Fully-grown birds do not show nostrils on the culmen therefore to

measure bill depth on fully-grown birds the edge of the front feathers is taken as a corresponding position (see Figure 5.10a).

Measurements can be taken from hatching until fledging although young birds tend to jump out of the nest between 23 and 41 days old and should be approached with care, especially in ground-breeding colonies. Observers should not handle or stress the smallest (youngest) nestlings. Time in colonies should be limited as prolonged exposure to direct sunlight can cause mortality of hatchlings.

Biometric data can be used to determine the relative condition of individual nestlings, and these can be examined in relation to a number of factors including brood size and the age-rank of chicks (see Platteeuw *et al.* 1995). Wing-length is a strong predictor of nestling age (in days) when accurate growth data are available. With this the timing of egg laying can be back-calculated

and related to condition relative to age and subsequent survival (in combination with colour-ringing). The bill shape (length related to depth) is a gross indicator of sex, which can be confirmed for individually marked colour-ringed birds later on, through observation of sex-based behaviour.

Age of young can be determined by stage of plumage development. Downy plumage appears after one week, this is first blackish brown (10–20 days), then gradually becoming greyer. The feathering of the forehead is a good indicator of age, chicks less than 20 days

having whitish fronts, becoming fully covered with down from day 26 on. This feature is a reliable predictor to choose chicks which can be ringed, especially useful in tree nests.

Wing and tail feathers develop strongly after 28 days being followed by scapulars and upper back from day 30–33. Fully developed wings appear normally not before day 40. At that time also belly, head and rump have no more downy feathers. Wings tend to increase in length after fledging between 50–55 days.

Depending on their condition, chicks can best be ringed between 25–35 days old. Younger chicks can have larger tarsi when condition is good and can bear 18 mm rings from 18–23 days on. In ground colonies an earlier ringing date gives less disturbance and allows the chicks to stay in the nest. From day 25 on chicks tend to walk away more often and after day 35 young tend to jump from lower bush nests if approached.

6 MOVEMENTS

T Bregnballe, J Y Paquet, S van Rijn and S Volponi

6.1 Introduction

Cormorants move extensively around continental Europe and beyond (Figure 6.1). After the breeding season young Cormorants first start to explore the environment around the nesting site thereafter they, as well as most adults, disperse in different directions, before initiating the real autumn migration. Not all Cormorants migrate south, indeed some remain within a few hundred kilometres from the breeding areas. The departure time from the northern parts of Europe ranges from July to December but most birds migrate south during September-October. Timing of later departure is partly related to drops in temperature. Some individuals appear to initiate their northerly spring migration from the Mediterranean (including North Africa) as early as late January. For example, colour-ringed birds seen in Tunisia in January have been resighted in The Netherlands by mid-February before subsequently reaching the breeding colonies in Denmark. In more northern areas like Switzerland, parts of Germany and The Netherlands, departure for spring migration mainly occurs in March. However, there is extensive variation in individual migration itineraries. Some individuals make many small 'jumps' between stopover sites whilst others tend to migrate fast by making long-distance flights separated by only

a few stopovers. Some Cormorants wintering in the southern and central part of the Mediterranean are known to have migrated up to 1,100 km north in spring within 3 days.

Cormorants from northern breeding areas may benefit from migrating south in a number of ways. For example, most fish move into deeper water and become less available to Cormorants with declining water temperature. Furthermore, some regions occupied by Cormorants during the breeding season are so cold during the winter months that standing fresh waters freeze for weeks, or even months, preventing birds from feeding. However, Cormorants wintering close to the colony are apparently at an advantage over long-range migrants because they are able to arrive early in the season and start breeding as soon as weather conditions become appropriate, leading to a breeding success above average. Birds that move south to warmer parts of Europe (and North Africa and the Middle East) will, once there, conserve energy due to higher air and water temperatures (van Eerden & Munsterman 1986, 1995). The southward migration also has costs of course due to the energy needed for migration and also because birds that migrate south tend to return and breed later in spring than those wintering close to the breeding areas.

Ringling programs are extremely valuable tools for increasing our knowledge about a number of topics relevant for understanding the ecology of Cormorants during and outside the breeding season and for developing knowledge-based management strategies to resolve conflicts. For example, the recoveries of ringed Cormorants found dead and the readings of codes on colour-rings attached to live birds gives researchers an opportunity to describe (a) how birds belonging to different breeding populations are distributed outside the breeding season (see Figures 6.2 and 6.3 for example); (b) how migration routes vary among individuals and populations; (c) how individuals time their migration; (d) how site-faithful individuals are towards certain staging and wintering sites; and (e) how Cormorants respond





Figure 6.2 Resighting locations of colour-ringed Cormorants from the Oostvaarderplassen colony (Netherlands) in 1983–2005. About 5,000 birds have been colour-ringed and about 20,000 resightings recorded.

Map courtesy of van Rijn & van Eerden 2007.

Figure 6.1 Flying Great Cormorants.

Photo courtesy of J Trauttmansdorff.



to climatic variation between seasons.

Marking individuals in breeding colonies with colour-rings and the subsequent reading of these rings in the field is an indispensable tool for quantifying demographic parameters, such as emigration and immigration, survival, age at first breeding, and age-related reproductive performance. As an example, Figure 6.2 shows the national and international resightings of colour-ringed Cormorants from a single colony in the Netherlands (van Rijn & van

Eerden 2007). Finally, the precision of estimates of survival for first-year birds and older ones can be improved by combining data from recoveries of birds found dead with resightings of colour-ringed birds in breeding colonies (e.g. Frederiksen & Bregnballe 2000, see also Figure 6.3).

6.2 Metal-rings

Metal rings, generally include country information in the form of an address to be contacted in the event the ring is found on a dead bird or, less commonly, the information on the ring has been read from a live bird in the field. Metal rings are the most common form of individual bird recognition but are often used alongside colour rings. Metal rings are the usual means by which the general public provide data, particularly from birds that are trapped or shot.

Cormorant chicks have been ringed with metal rings in Europe since at least the 1930s. The use of metal rings increased markedly after the mid-1970s. Chicks have been ringed with metal rings made of aluminium or steel. Rings made of steel are now recommended because they have a higher resistance to wear. The use of metal rings is entirely coordinated by national ringing centres.

Since the late 1970s metal rings have often been used in combination with colour-rings. Ringing with metal rings alone (i.e. not in combination with colour-rings) is usually carried out because the only aim is to obtain information about birds found dead or because it is too

costly (in terms of man power) to ring with colour-rings and handle the resightings afterwards. Furthermore, ringing activities might be limited to the use of metal rings only in order to minimise the duration of disturbance at the breeding colony.

Interpretation of ring recoveries from birds found dead

Information about recoveries of ringed Cormorants found dead is frequently used in research aiming to identify the geographical extent of the breeding areas from which staging and/or wintering Cormorants originate. However, the main interpretive problem here is that Cormorants have not been ringed simultaneously throughout their breeding range in proportion to the numbers actually breeding in the different countries. Thus for example, the lack of recoveries on wintering sites in middle European countries of Cormorants ringed in Belarus probably simply reflects an absence of ringing activities in Belarus and does not mean that Cormorants from Belarus would not migrate this far to the west if appropriate.

Recoveries of rings are also often used to define the areas that Cormorants from a certain breeding area use outside the breeding season and to identify which of these areas are of greatest importance (see for example Figure 5.3). The major problem here is that mortality risks and recovery probabilities will vary geographically, thus affecting the conformity between the geographic distribution of ring recoveries and the spatial distribution of the population under investigation.



Figure 6.3 Distribution of Cormorants ringed in the Danish Vorsø colony (central Denmark) and found dead during winter (20 November–20 February) showing a total of 552 recoveries from 1947–2008.

Bregnballe & Gregersen unpublished, ring recovery map by T Bregnballe.

Similarly, there are also difficulties in using ring recoveries from dead birds to describe the temporal use of staging and wintering areas and also the timing of movements. For example, partly because birds are rarely recovered on the day they die, recoveries of birds found dead will tend to give a picture of later departure and later arrival than was actually the case (Bregnballe *et al.* 1997). Another difficulty is that an increase in the number of recoveries from a certain region at a certain time of the year may be an effect of a local temporary increase in mortality (and/or in reporting rate of dead birds) rather than an effect of presence of higher numbers of Cormorants.

For example, the number of Cormorants recovered drowned in fishing nets might depend on the number of nets in use (Bregnballe 1999), and the risk of dying in Dutch, German and Swiss lakes is thus apparently higher in January than in autumn (Bregnballe *et al.* 1997). The time periods of culling activity and/or Cormorant control actions in various countries also have to be taken into account as these may also bias the timing and locations of ring recoveries.

6.3 Colour-rings

The Great Cormorant is a good example of the great interest in long-term, intensive individual bird

marking operations, yielding a wealth of results on population dynamics, migration, timing, reproduction, and behaviour as shown in numerous papers using colour-ring data (e.g. Fiedler 1999, Frederikson *et al.* 2002, Sackl & Zuna-Kratky 2004, Bregnballe 2006, Bregnballe *et al.* 1997, 2006, Hénaux *et al.* 2007, van Rijn & van Eerden 2007).

Since the early stages of the species' recovery, Great Cormorant chicks have been intensively marked with colour-rings in several important breeding populations throughout Europe. The different colour-ringing schemes have been well coordinated, providing motivating exchange between observers and program managers. This has ensured that no miss-match occurred with different individual birds carrying the same mark. Colour-rings are relatively easy to read on Great Cormorant legs, thanks to the perching behaviour of this species (see Figure 6.4).

Usually, colour-rings are placed on 21–27 (but up to 35) day-old nestlings (see Figure 6.5). However, recently the colour-ringing of Cormorants captured as adults has been initiated in Spain (see Figure 6.8). Importantly, at all times (and in all situations), Cormorant rings should only be fitted by specially trained and licensed ringers (see Figure 6.6). One or several colour rings are placed on the tarsus, along with a traditional metal ring of the national ringing centre. Basically, there are two types of colour-rings used on Cormorants:

- A single large PVC ring of one colour, carrying an alpha-numeric code of generally 2 or 3 (occasionally up to 4) characters that can be read from

a distance through a telescope. This type of ring is by far the most frequently used in Europe. The colour ring is placed on one tarsus, while the traditional metal ring is placed on the other leg. A bar may separate the digits or letters on the colour-ring, thus increasing the number of combinations. However in such cases at a distance it may seem that there are two rings on the leg instead of one.

- Several smaller PVC rings of different colours, creating a multi-ring combination, including the metal ring as one of the rings within the combination. There is no alpha-numeric code to be read on this type of marking and so the exact colour-ring combination, including the metal ring has to be recorded to identify the individual.

The coordination of all colour-ring schemes is undertaken in Europe by the IUCN-SSC Wetlands International Cormorant Research Group. It is very important that anyone wishing to colour-ring Great Cormorants first contacts the European coordinator of this scheme, before even planning, ordering, or making colour rings. The reference website for colour-ringing Great Cormorants is the Cormorant Research Group official website: <http://Cormorants.freehostia.com/index.htm> and the current colour-ring coordinator for Europe can be contacted via: Stef.van.Rijn@rws.nl

6.4 Reading colour-rings on Cormorants

The best way of finding a ringed Cormorant in the field is to scan a group of birds while they are

perched with their legs exposed. Prior knowledge of the preferred resting places of Cormorants in a particular area is thus essential. Usually, night roosts are good places to find ringed birds because they are used by many individuals throughout daylight hours as well as at night. However, although day roosts hold fewer birds than night roosts do, they can be places where the birds' legs are easier to observe. For instance day roosts often form on such sites as walls and trees along rivers, dams, sluices, and high tension poles. Colonies are also good places to spot ringed birds, although they are more sensitive sites to watch without causing disturbance. Care must be taken in all situations, in the breeding colony as well as at wintering sites, because any unnecessary disturbance to birds should always be avoided.

When perched in trees, Cormorants are more prone to show their legs if a light wind is blowing. In these conditions they have to stand up a little bit and tend to move more frequently to keep their balance, thus increasing the opportunities for their leg-rings to be visible to an observer. In a night roost, during calm and cold weather, birds tend to stand/sit in a squat position with their legs tucked well into their plumage and so their legs can be extremely difficult to check. In these circumstances, the best opportunity to see the bird's legs is when a new bird comes back to the roost because the other birds stand up, ready to defend their branch or place in the roost, as the newcomer tries to land amongst the group.

A good telescope is essential to read colour-rings, particularly if fitted with a 20–60x zoom,

although a fixed wide-angle ocular (e.g. 30x) or a pair of binoculars are preferred by some observers because it is then easier to scan birds in flight and/or a larger number of perched birds (if they can be approached close enough without disturbance). Depending on weather conditions, colour rings are normally readable up to 300 m (sometimes 700 m). When using a telescope, a sturdy tripod ensuring maximum stability is essential.

The code on the ring should be read vertically e.g. parallel to the leg axis. Do not forget that the codes are repeated (normally 3 times) all around the ring, so if you see only a part of the letters/numbers, you may be able to see the rest of them on the other side of the ring. Be careful to determine the reading direction for the code on the ring (it can be either way, up or down), to ensure that you correctly read '6' and not '9' by comparison with the other letters in the code sequence. Confusing codes are generally avoided by ringers, or only used once (e.g. '666' and '999', and letters like N, H, S). For the same reason not all the letters in the alphabet are used: in Italy, for example, only 15 letters are used. Sometimes the ring code may also include a vertical bar (see Figure 6.4) or far less commonly a horizontal one.

Needless to say, it can be really useful to photograph or sketch any ringed bird, (and to send them to the ringing scheme manager), even if only low resolution pictures are possible. Such photographs or images can hold important details such as the bird's plumage, size, or sex.



Figure 6.4 An adult Cormorant with red colour ring on its left leg and a metal ring on its right. Photo courtesy of J Helder.

6.5 Reporting sightings of ringed Cormorants

As well as the ring code, a number of other essential, very important and useful pieces of information should be recorded if at all possible. An essential and supplementary check-list of recording details is given overleaf (Table 6.1).

In order to provide the most comprehensive and useful information possible to the ringing scheme, it may be useful to complete a simple colour-ringing reporting sheet that can be downloaded as an excel file at the following website: <http://Cormorants.freehostia.com/index.htm>

In every country, ringing operations are coordinated nationally by a national ringing centre choosing from a list available here: http://www.euring.org/national_schemes/contact_schemes.htm and thus ensuring that a unique metal ring is associated with an individual bird, whatever the species, and that the record of this ringed bird is kept in a centralised database. No ringing operation should be conducted without the agreement of the national ringing scheme. Colour-ringing schemes are however not always coordinated by the official national ringing centres (as they are for the traditional metal rings), although colour-ring users sometimes do have an obligation to report their data to their respective ringing centre.



Figure 6.5 Photo left — Cormorant chick ringed with a metal ring on tarsus (Estonia, June 07), Photo courtesy of Stef van Rijn and Photo right — one marked with a plastic colour ring. Photo courtesy of M Marinov.

If a Cormorant with a metal ring is observed or found (see Figure 6.7 and also Figure 6.8), send as much relevant information as possible to the ringing centre in your country (see list on the Euring website: www.euring.org). If a colour-ring sighting

is being reported, the report should be sent to the corresponding scheme manager. According to the code on the ring, the relevant ringing scheme can be found using the following updated website: <http://Cormorants.freehostia.com/index.htm>



Figure 6.6 Field workers measuring and ringing Cormorant chicks. Photo courtesy of M Marinov.



Figure 6.7 Example for metal ring recovery: migrating bird shot during Cormorant control actions in Austria, an immature male ringed 17.06.03 in Finland and shot 31.01.04 in Austria. As well as indicating migration routes, graphical documentation of ring recoveries can be used to show plumage characteristics for birds of known age.

Photo courtesy of R Parz-Gollner.

If the relevant scheme can not be found however, do not hesitate to send the data to any coordinator on the list who will then try their best to find the appropriate scheme for that particular ring.

6.6 Some ideas for using colour-rings for new studies

Large-scale colour-ringing offers opportunities not only for the various specific colour-ringing schemes themselves, but also for those interested in Cormorants anywhere in Europe. There are several examples of local studies, not themselves based on directly ringing the birds but on the systematic recording of colour-ringed Cormorants in specific locations (Reymond & Zuchuat 1995a and 1995b, Yésou 1995, Retter 2000, Paquet *et al.* 2003, Galván 2005). Such systematic recording of colour-ringed Cormorants can offer unique insights on the use of a specific area, but can also provide details on behaviour, local movement, local site-fidelity, and the turn-over of individuals. Such local information can be very useful in the planning of local Cormorant counts (see sections 3.3 and 3.4).

It is possible to organise regular surveys for ringed Cormorants at one or more roost sites using several observers who are able to organise themselves and exchange information. For example, if roost counts are being organised (see section 3.3), it is highly valuable to encourage observers to have a closer look at Cormorant legs and to record any sightings of metal or colour rings that are observed.

Table 6.1 Details of information to be reported when providing a Great Cormorant resighting.

| What to report? | Relative importance | Comments |
|----------------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ring code | Essential | Every detail is needed, including the position of the colour-ring (left or right leg) and the direction of the code-reading (top-down or down-top). Any uncertainty in the reading must be reported (e.g. for potentially confusing letters such as 'K' or 'X'). The position (or absence) of a metal ring (usually on the other leg) should be noted. |
| Place, location | Essential | Preferably with the geographic coordinates of the site. These can be easily found using Google Earth®. Take care to communicate the format used to report the coordinates (decimal degrees, degrees and minutes, or otherwise). |
| Date | Essential | If a colour-ring bird is repeatedly seen at the same location, all the observation dates are useful, not only the date of first sighting. |
| State of the bird | Essential | Was it alive or dead? If dead, approximately how long? |
| Age | Very important | It is useful to check if the bird is adult or immature (this can also help sorting out any misleading readings). |
| Name of the observer | Very important | If possible with e-mail address. |
| Habitat | Useful | Especially if no geographic coordinates are given. Be as precise as possible e.g. bird was along a river, in a harbour, in trees, in a colony, etc. |
| Signs of breeding activity | Very important | For birds resighted inside breeding colonies, it is of great value to know whether or not the bird was engaged in a breeding attempt. For example, it is sitting on the rim of a nest. |
| Type of location | Useful | For example, is it a resting bird in a night roost? Or a bird seen on a day roost? Or is it on or close to some foraging ground? |
| Flock size | Useful | Record the number of other Cormorants present at the same site. |
| Time | Not essential | Can be reported if recorded. |

6.7 More general information, selection of useful links

Further useful information about bird ringing, as well as related issues dealing with bird migration, relevant

literature and download material can be found on the web, for example under the following links:

BTO — Bird Ringing in Britain and Ireland: www.bto.org/volunteer-surveys/ringing/ringing-scheme



Figure 6.8 Example for metal and colour ring recovery showing site fidelity, movements and fly-ways between breeding and wintering sites: this Cormorant has been ringed as a chick in Sweden with a metal ring on the right tarsus. Wintering in Spain the bird was captured a second time as an adult on 03.03.2007 and a colour ring was fitted on the left tarsus. Two years later the bird was sighted and identified by reading the letters on the yellow plastic colour-ring in the field and the bird was reported on 22.08.2009 to be on the southern coast in Sweden again.

Photo courtesy of Joan Aymerich, Grup d'Anellament Calldetenes Osona, Spain.

EURING (The European Union for Bird Ringing): www.euring.org;
see download link to get a copy of the Euring Brochure (2007) Bird ringing in science and conservation.

European Colour Ring Birding:
www.cr-birding.org

Wetlands International:
www.wetlands.org

Waterbird migration:
<http://www.wetlands.org/Whatwedo/Savingwaterbirds/Flywaysforwaterbirds/tabid/772/Default.aspx>

Wetlands International — follow the bird: <http://followthebird.wetlands.org/BirdsWeFollow/tabid/1539/language/en-US/Default.aspx>

Wetlands International (WI) Cormorant Research Group (CRG):
<http://Cormorants.freehostia.com/index.htm>

7 INTRODUCTION

Part Two — Working with Fishes

D N Carss, R Haunschmid and I C Russell

This section of the **INTERCAFE** Field Manual is devoted to a brief overview of some of the field methods available for assessing fish numbers in freshwater and coastal habitats. It aims to provide the reader with a description of the commonest techniques used by researchers and fishery managers for assessing fish populations and of the problems associated with deriving reliable measures of fish abundance. Clearly, in the context of the Field Manual, interest in fish populations is due to the general concern over the potential ‘impact’ of Cormorant predation on fishes. However, in contrast to Part One, there is less focus here on the application of standard methodologies for fish assessment, because aquatic habitats and fish populations vary widely necessitating the use of a broad range of sampling and assessment techniques in different situations. Further, in many instances, well-established fishery assessment protocols are already followed. Nevertheless, we hope that readers will gain a better understanding of the work required to answer the question ‘How many fish are there in that lake, or stretch of river, or along that coast?’ and of the constraints on the resulting data.

Many of the ecological issues associated with both counting

Cormorants (and just as importantly, choosing the most appropriate technique to do so) and interpreting the resulting counts are similar to those that have to be considered when attempting to count fish. An understanding of the abundance of fish is a vital requirement for any informed evaluation of Cormorant-fishery interactions and for assessing the effect of measures aimed at reducing the birds’ impact on fish.

Across Europe, there is a broad diversity of fish species and a wide variety of habitats in which they live. Unlike Cormorants, fish are seldom,



Figure 7.1 Typical river systems are dominated by ‘Trout Zone’ habitats in their headwaters. Photographs—Shutterstock.



Figure 7.2 Typical river systems are dominated by ‘Bream Zone’ habitats in the lowlands. Photographs—Shutterstock.

if ever, conspicuous and so counting them in an accurate, reliable, and repeatable (i.e. ‘biologically meaningful’) way is not easy and is commonly constrained by time, methodological and financial limitations. Typically, fish population assessments are based on samples of the ‘population’. Such data are thus not absolute counts but an index of the population given in such terms as ‘biomass’ or ‘standing crop’ (the mass of fish of a particular species per unit area), ‘density’ (numbers per unit area

or unit volume), or ‘catch per unit effort’ (CPUE: typically the number/weight of fish caught by a particular fishing gear over a standardised time period). However, such sample catches/counts are commonly also extrapolated up to arrive at best estimates of overall fish numbers in a wider area.

It is only through knowledge of both fish ecology and behaviour that researchers can hope to assess populations. It is not the intention to review all the relevant literature

here but to give the reader a feel for the complexity (in both time and space) of the ecology of fishes and their relationships with the diverse habitats in which they occur. This complexity has consequences for both the appropriateness of available methods to assess fish numbers and the likelihood of identifying and/or quantifying any Cormorant impact on fish at a specific location.

7.1 European fish diversity

The published literature on fish diversity and distribution, behaviour, and ecology is vast and beyond the scope of this summary. However, a good introduction is provided by Wheeler (1978), Pitcher (1993) and Wootton (1990). Although the fish fauna of Europe is not particularly rich, the ‘Handbook of European Freshwater Fishes’ (Kottelat & Freyhof, 2007) lists 522 freshwater species plus 24 marine species that are also found in freshwater. There is an even wider diversity of marine fishes around Europe’s coasts (Hart & Reynolds, 2002). There is thus a huge diversity of fishes in European coastal and freshwaters, closely linked to specific habitats and environmental conditions.

By necessity, the techniques for investigating fish populations are also numerous and diverse. Knowledge of fish ecology and behaviour also forces the researcher to consider the term ‘population’ and this concept is discussed below. Although much of the following discussion focuses on freshwater fishes, it will often be analogous to coastal situations.

7.2 Fish distribution and movements

Fish species are distributed throughout particular waters in both space and time (Wootton 1990). A range of factors influence the distribution and abundance of fish populations, including seasonal factors and the life-history characteristics of the species themselves (e.g. migration, habitat requirements of different life stages, etc.). For instance, many juvenile fish occupy a specific habitat which changes as the fish grow older - individuals of some species spend all their lives close to where they were spawned whilst other species may make long migrations covering 100s or 1,000s of kilometres. Some fish also make vertical migrations, with individuals moving up and down in the water column at anything from daily to seasonal frequency. Many adult fishes also have particular spawning habitat requirements. Apart from specific movements for activities such as spawning, many of the movements made by fishes are likely to be made in relation to the need to forage and to avoid predators, and also in response to changing environmental variables such as light levels and water temperature.

7.3 Fish communities and assemblages

Individual fish live within complex webs of interactions (e.g. predator-prey relationships, competition, reproduction) and processes (e.g. the flow of energy and nutrients through the web) that can affect (or be affected by) that individual (Wootton, 1990). All those fish

in a defined area or habitat that interact (directly or indirectly) form a 'community' and, within a community, fishes that exploit the same resources in a similar way are termed 'guilds'. The term 'assemblage' is often used to describe all fish species in a defined area, regardless of whether they interact or not. Often, several different species may have broadly similar habitat requirements (at least at some time in their life-cycles) resulting in assemblages that are associated with particular broadly-defined habitat types.

In freshwater, broad-scale distribution is chiefly controlled by climatic, topographical and hydrological differences. In rivers, for example, there is often a continuous increase in species richness (i.e. total number of species) with progression downstream. Thus, a typical river starts with a zone (the 'Trout Zone') characterised by steep gradients, fast flowing water and cool temperatures and holds Brown Trout (*Salmo trutta*), Atlantic Salmon (*S. salar*), Bullhead (*Cottus gobio*) and Stone Loach (*Barbatula barbatula*). The 'Grayling Zone' follows (and is slightly warmer) and can hold all the above species with the addition of Grayling (*Thymallus thymallus*), Minnow (*Phoxinus phoxinus*), Chub (*Leuciscus cephalus*) and Dace (*Leuciscus leuciscus*). This, in turn, leads to the 'Barbel Zone', which has a gentle gradient, moderate water flow and temperature, with a good oxygen content and mixed silts and gravels. It is characterised by the previously mentioned upstream species plus Barbel (*Barbus barbus*), Roach (*Rutilus rutilus*), Rudd (*Scardinius erythrophthalmus*), Perch (*Perca fluviatilis*), Pike (*Esox lucius*) and



Eel (*Anguilla anguilla*). Finally, the river enters 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 the other zones and the substrate is 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 which is also characterised by Bream (*Abramis brama*), Tench (*Tinca tinca*) and Carp (*Cyprinus carpio*).

Overlaid on this, as one moves westwards in Europe from the Danube, the freshwater fish fauna gradually becomes more impoverished in terms of species numbers. At the far west (the UK, Ireland and Norway) the native freshwater species are actually only those that became trapped in rivers as sea levels rose at the end of the last Ice Age and many of the current fish fauna are present entirely as a



Figure 7.3 Many European river systems have been altered from ‘natural’ habitats (left) to ‘modified’ ones (right) — often to the detriment of the fish communities within them. Photographs—Shutterstock.

result of human activities (Wheeler 1978). However, at a more local scale prevalent habitat types and anthropogenic factors are likely to be more important in regulating the distribution of different fish species.

In coastal areas, there is a similar variability in fish communities often associated with salinity, water temperature, coastal structure, water currents, substrate type and algal (seaweed) abundance and cover.

7.4 Ecosystem-level factors affecting fishes

The following subsection is compiled primarily from information taken from work undertaken from the Millennium Ecosystem Assessment (Hassan *et al.* 2005). Ecosystem-level factors affect fish in fresh and coastal waters through the fishes’ relationships with aquatic habitats and sensitivities to environmental

changes and anthropogenic activities. It is generally recognised that the distribution of freshwater fishes has been altered more radically by human activity in the last few hundred years than was ever achieved by natural processes over the preceding millennia. Inland water habitats and species are generally in a worse condition than those in other ecosystems (Hassan *et al.* 2005). These authors conclude that more than 50% of inland waters (excluding lakes and rivers) have been lost in parts of Europe during the last century.

Human activities have affected freshwater fish populations indirectly by changing aquatic habitats. Habitat degradation is widespread and the species diversity of inland waters is among the most threatened of all ecosystems. The direct drivers of degradation and loss are well-documented and include changes in land use and cover as a result

of vegetation clearance, draining and infilling, often related to the expansion of agriculture or infrastructure, eutrophication, hydrological modification and pollution, or for use in aquaculture, agriculture or industry. The construction of dams and other structures along rivers has resulted in fragmentation and flow regulation in almost 60% of the large rivers systems in the world. For example, the first 1,000 km of the River Danube can be considered an almost uninterrupted artificial waterway passing through 59 hydropower dams. In addition, freshwater fish populations have also been influenced directly by targeted action (e.g. fishery management initiatives, harvesting, species introductions and transfers).

The FAO’s (Food and Agriculture Organization of the United Nations) latest global assessment of freshwater fisheries (1999) shows that most capture fisheries that rely

on natural reproduction (perhaps now around only one-third of all freshwater fishery production on a global scale) are over-fished or are being fished at their biological limit, and that the most important factors threatening them are fish habitat loss and environmental degradation. Similarly, coastal ecosystems are experiencing some of the most rapid environmental changes and, in all regions, coastal fisheries have depleted fish stocks.

The human population of Europe has almost doubled since 1900 and agriculture and industry have developed massively. According to the UN Environmental Programme, almost 60% of Europe's natural wetlands have now been 'destroyed', leaving freshwater species declining at an increasing rate (e.g. see Kottelat & Freyhof, 2007). Recent estimates suggest that nearly 40% of European freshwater fish species are threatened with extinction. However, many new water bodies have also been created in recent decades as a result of human activity (e.g. sand and gravel extraction, new recreational fisheries, etc.) and water quality is also improving in many places as discharge regulations have been brought in, effluent treatment measures improved and with greater general awareness of environmental issues.

Fish stocking is seen as an important and commonly-used tool in the management of fisheries for commercial, recreational and conservation purposes — with fish being stocked for mitigation, enhancement, restoration and the creation of new fisheries. The scale of such stocking is immense with many thousands of stocking events involving many millions of fish

occurring each year (Hickley 1994), although many of these fish are simply relocated between natural sites rather than being farm-reared. For example, in England and Wales 6,000 separate fish introductions take place each year involving some 2 million fish (Environment Agency, undated). Similarly, at Loch Leven a freshwater lake in Scotland, over 1,318,000 (7–15 cm long) Brown Trout (*Salmo trutta*) were released between 1983–1994, plus an additional 40,000 (28–29 cm long) Rainbow Trout (*Oncorhynchus mykiss*) in 1993 and 30,000 in 1994 (Carss *et al.* 1997). However, there is increasing concern over the potential risks associated with the stocking of fish, particularly in relation to ecological imbalance and changes in fish community structure, as well as the transfer of disease and the loss of genetic diversity (see Cowx 1999, Carvalho & Cross 1998, McGinnity *et al.* 2003).

7.5 Defining fish populations

Given the complexity of fish distribution and movement in both time and space, it can be difficult to define a 'population'. A simple definition would be a group of fish of the same species that are alive in a defined area at a given time. The area may be defined arbitrarily for the convenience of researchers/managers (e.g. as a stretch of river or coast) or may be ecologically meaningful for the population under study (e.g. a lake). These different approaches need to be borne in mind when considering what effects predators such as Cormorants may have on a 'population' of fish. Rather than populations, many fishery managers use the term 'stock' — essentially

meaning a 'population' of fish that is exploited by a fishery and which may be subject to some type of management. Thus, 'stock' is typically used for more commercially important species. However, it is important to consider that predation by Cormorants, for instance, on a fish stock may not have the same biological meaning as predation on a fish population. To further complicate matters, many fisheries interests measure Cormorant impact in terms of the reduction in their fish catches. In general terms, larger stocks would be expected to result in better catches, and this has been demonstrated for many different fish species. However, this does not always apply and a range of factors may influence the relationship between catches and the underlying stock size. It has to be pointed out that the relationship between fish catches, fish stocks and, ultimately, fish populations is likely to be extremely complicated and very difficult to quantify in many cases.

As well as the complexity of fish distribution and movement in both time and space affecting what is understood to be a 'population' of a particular fish species, the concept is further compounded when several species live together in the same habitat as an assemblage. Moreover in almost all waters, given that several members of an assemblage may have direct interactions with each other, it becomes extremely difficult to consider one fish species in isolation in an ecologically meaningful way. This is particularly important when considering potential Cormorant predation, as these birds are generalist predators which tend to take their prey opportunistically in relation



Figure 7.4 The definitions of fish populations and stocks, and their relationship with catches are all issues adding complexity to understanding the population ecology of fishes. Photograph—Shutterstock.

to their general ‘availability’ in particular habitats. ‘Availability’ is a particularly difficult parameter for researchers to measure but is probably influenced by several factors — a combination of the relative abundance of various species and size-classes of fish, together with the ease with which they can be located, caught, and eaten (Marquiss *et al.* 1998). For further discussion on Cormorants as generalist predators, see section 10.6.

7.6 Estimating fish abundance

From the above, it is clear that considerable research effort is required to rigorously quantify a particular fish population/stock. In order to understand the population dynamics of a specific stock, the following information is ideally required:

- Estimates of population abundance (fish numbers) for all stages of the life-cycle.
- Measures of the rate of change of abundance for these stages.
- Mortality, growth and fecundity (potential reproductive capacity) rates — which are all size- (age) related and which may also be functions of the density of the population.
- The relationship between the abundance of the sexually mature portion of the population and recruitment to a defined age (or size) class — i.e. the stock-recruitment relationship.
- The amount of fish flesh generated by a cohort as the fish grow and die — in order to assess production.

Deriving such information is both challenging and expensive, and typically requires a continuous process of monitoring and

assessment (often over many years). This level of monitoring is thus usually limited to large, commercially-valuable stocks, and is unlikely to be available for many fish populations that are subject to Cormorant predation.

While many commercial fisheries in larger waters will be subject to regular assessment by the appropriate authorities, such assessments do not commonly extend to smaller water bodies, private fisheries, etc. Thus, the information available for fisheries subject to predation by Cormorants (e.g. stock size and composition, catches, etc.) will vary enormously. Although it cannot be assumed that parallel fisheries data will be available alongside that of Cormorants, it is nevertheless possible that some studies on fish at specific sites will be useful in this context.

The techniques described in the following chapter do not necessarily provide all the data required to quantify the population dynamics of a fish species (or the impact of Cormorants on a particular species or on members of a fish community). However, they are the most common methods used by researchers to answer the question ‘How many fish are in that water body?’ Furthermore, these methods are important to consider as they are usually the ones that provide fish data for any investigation into Cormorant impact at fisheries. The subject of scientific attempts to quantify such impact — through the integration of both Cormorant and fishery data — is the subject of the final chapter of the **INTERCAFE** Field Manual.

8 ESTIMATING ABUNDANCE OF FISH SPECIES

S França, R Haunschmid, I C Russell and C Vinagre

As noted in the last chapter, there are numerous different techniques for assessing fish abundance (e.g. see Nielson & Johnson 1983, Gabriel *et al.*, 2005). It is not possible to review these in detail here, but the following provides a brief summary of the most common fish sampling methods that might be applied in assessing fish stocks and possibly used as part of an investigation into Cormorant/fishery conflicts and assessing Cormorant impact.

Fishing gears may be either ‘active’, where the gear is moved towards the fish and they are caught in it, or ‘passive’, where the equipment is static and fish swim into it and are captured (Hemingway & Elliot 2002, Jennings *et al.* 2001). Active gear tends to provide almost instantaneous samples from more or less defined areas, while passive gear usually integrates the collection of fish over a longer period of time. Passive gear is therefore most appropriate for sampling areas that are poorly defined or unknown (Hemingway & Elliot 2002). The choice of equipment also depends very much on habitat type and target fish species.

For convenience, fishery sampling techniques have been split between

those mainly used in marine/coastal fisheries, and those more commonly used in freshwater, although some apply in both. Many of the limitations relating to the estimation of fish abundance apply equally in both habitats.

8.1 Estimating abundance of marine and coastal fish species

As discussed in Chapter 6 of the INTERCAFE Field Manual, a wide range of factors influence the distribution of fish populations in the marine environment, although climatic and oceanographic influences (e.g. ocean currents) are probably the main influences. Fish distribution is also influenced by seasonal factors and by the life-history characteristics of the species themselves (e.g. migration, the habitat requirements of different life stages). Thus, the use of appropriate, targeted sampling methods is needed when estimating fish species composition and abundance. A brief description of some of the main sampling methods for marine and coastal areas is given below.

8.1.1 Trawl nets

Trawl nets are funnel-shaped nets which can either be towed across

the seabed or through the water column. Fish become trapped in the tail of the net — known as the ‘cod-end’ (Hemingway & Elliot 2002). Fish of different sizes and species have very different ‘catchability’, and this also varies with gear design (Jennings *et al.* 2001). There are three main types of trawl nets, and these are distinguished by the way the mouth of the nets is kept open, the habitat in which they are used, and the target fish species:

Otter trawls — the net of an otter trawl is kept open by so-called ‘otter boards’ and is used for fish swimming in the water column near the seabed (‘demersal roundfish’ and flatfish), fish swimming in open water not close to the bottom (‘pelagic fish’), crustaceans and molluscs. The gear is most commonly used in estuarine and coastal waters.

Pair trawls — are deployed between two fishing vessels and are used to capture both demersal (generally bottom-living) and pelagic (generally living in the water column) fish. The gear is typically used in shallow water.

Beam trawls — the net is held open by a beam and has a heavily weighted footrope on the bottom. It is designed to exploit demersal fish and shellfish



Figure 8.1 Fish sampling with a trawl net in coastal habitat.

Photograph—Shutterstock.

and can be used in estuarine and coastal waters. It is also commonly used for scientific sampling.

The aim of a trawl survey is usually to get indices of fish abundance or density for a specific survey area that are then extrapolated to give values for a larger study area on the assumption that the necessarily limited sample is representative of this wider area. However, as trawls invariably select particular species (or sizes) of fish, they are very unlikely to provide information on the relative abundance of the fish assemblage(s) in a particular area. Similarly, trawling will only be possible in particular water bodies (or areas within them). For example, they may not be appropriate over rocky habitats or in those with substantial aquatic vegetation, and so may not be able to provide data for some Cormorant foraging habitats.

8.1.2 Gill nets

Gill nets are widely used in the marine environment, but can also

be used in freshwater. Typically these comprise single sheets of netting (either fixed or drifting) which are hung vertically in the water column to capture demersal or pelagic roundfish (i.e. non-flatfish species living in the water column either close to the bottom or not), which become caught in the nets by their gill covers.

However, two or more sheets of netting can also be hung together to create specialised gill nets known as trammel nets. For demersal species the nets are fixed to the seabed by a weighted ground rope and anchors. Gill nets for pelagic fish are suspended by floats at, or close to, the surface, and one end of the net may be attached to a boat (Hemingway & Elliot 2002).

Gill nets tend to be highly selective, small fishes swimming through the mesh while larger ones are not retained in it. However, the mesh sizes, lengths and depths at which the nets are positioned can be varied according to the target species. Standard survey gill nets for fresh waters have been developed which contain a range of mesh sizes so that they will catch individuals of lengths from 2 or 3 cm to in excess of 1 m. A good reference to the standard gill net used in European fresh waters as required by the European Committee for Standardisation (CEN) is given by Appelberg (2000).



Figure 8.2 Various freshwater fish species sampled with a gill net.

Photograph—Shutterstock.



Figure 8.3 Setting (*left*) and extracting catches from (*right*) a gill net set in coastal habitat.

Photos courtesy of Marisa Batista.

Thus, as for trawls, gill net catches may not be completely representative of the relative species abundance (or size-range) of the fish assemblage(s) in a particular area. However, if used with care gill nets can be operated efficiently in most habitats. One major disadvantage of gill nets is that the fish caught in them are usually recovered dead, and they can also catch, and kill, non-target organisms, notably aquatic mammals and diving water birds.

8.1.3 Seine nets

Seine nets are usually simple sheets of netting stretching from a lead line, designed to keep the bottom of the net adjacent to the substrate, and a floating headline. The nets may also incorporate a cod-end in the centre. Seine nets are used in shallow water and are often operated from the shore, when the net is either set by a boat or is walked out from the shore and set by hand. The net is

then gradually pulled ashore. Fish landed by this technique are usually in excellent condition (Jennings *et al.* 2001). Seine nets are commonly used in freshwater habitats and estuaries as well as on the coast.

Seine nets may have quite fine mesh, thus enabling them to capture all but the smallest fishes. However, because efficient capture depends on the net being worked smoothly through the water (particularly



Figure 8.4 Very fine mesh (*left*) allows all but the very smallest fishes to be sampled. Some seine netting operations require considerable manpower (*right*) and here sandy shores offer ideal sampling habitat for seine netting.

Photographs—Shutterstock (*left*), Catarina Vinagre (*right*).



Figure 8.5 Fish sampling with a seine net in a rocky coastal habitat where great care must be taken so that the net does not snag on the bottom and allow fish to escape. Photo courtesy of Ana Pego.



Figure 8.6 Preparations for fish sampling with longlines.

Photograph—Shutterstock.

when pulling it to the shore), they cannot be used in habitats with dense aquatic vegetation or rocky substrates as nets tend to get snagged on these obstructions. Similarly, depending on the depth of the seine net itself, and the water it is being fished in, this technique will not always sample the entire water column.

8.1.4 Hydroacoustics

Hydroacoustic techniques are used most extensively in marine areas. However, the techniques also have applications in larger freshwater bodies where other methods can be difficult to apply (Winfield *et al.* 2009). This method can provide an overall indication of fish abundance in an area and an approximate indication of individual sizes, but it does not provide reliable information on species composition. Furthermore, this technique as usually deployed cannot detect fish in the top 2 m

or so of the water column, which may be a problem for sampling some species. Experience in marine fisheries has shown that comprehensive calibration of the equipment, coupled with accurate estimation of the acoustic target strength of the species present throughout their size range, is crucial before reliable, quantitative estimates can be generated.

8.1.5 Longlines

Longline fishing uses large numbers of baited fish hooks attached at intervals to a main line (the longline) by means of branch lines called snoods. Each snood is a short length of line attached with a clip or swivel and with a baited hook at the other end. Longlines can be set at the water's surface or on the bottom and be either fixed by means of an anchor or left drifting. Hundreds or even thousands of baited hooks can hang from a single

line in some commercial (usually marine) fisheries. However, the technique is non-selective for fish species and sizes, and it can result in considerable catches (and mortalities) of non-target organisms, especially diving water birds.

8.1.6 Catch data

Information on catches is widely used for assessing fish stocks, particularly those in the marine environment. Such data are of particular value where they are accompanied by a measure of effort so that data can be presented as catch per unit effort (CPUE) indices. Coordinated catch monitoring programmes operate in most commercially exploited fisheries. For species/fisheries subject to such independent sampling, or where a reliable licensing and catch reporting system operates, catch data are likely to be particularly reliable and useful.

8.2 Estimating abundance of freshwater fish species

There are various techniques that enable the status of freshwater fish stocks to be assessed, and the objective of any survey will be central to assessing which of these may be appropriate in any situation. For example, various techniques (e.g. electro-fishing, seine netting, or gill netting) might be used to provide 'snapshot' estimates of a fish population in a representative area/stretch of water and enable results to be extrapolated to the whole water. Other techniques (e.g. observation by divers, hydro-acoustics) may provide information on fish stocks without the need to handle the fish, while fish counters can be used to record numbers of fish over an extended time period (e.g. to assess the numbers of adult Atlantic salmon *Salmo salar* and migratory brown 'sea' trout *S. trutta* entering river systems). However, the choice of method may be dictated as much by considerations of cost effectiveness as by the accuracy of the results obtained. As an example, a summary of fish sampling methods used in the UK to evaluate the status of fish stocks is given in Table 8.1 (Cowx 1995).

Applied correctly, many freshwater sampling techniques can be used to generate quantitative or semi-quantitative estimates of freshwater fish biomass, but in some situations this may be impractical due to river topography, current velocity, water depths, obstructions in the water course, or because they are potentially damaging to a valuable fishery resource. Provided enough sites are sampled within a catchment, then results from a

Table 8.1 Summary of fish sampling methods used in the UK to evaluate the status of fish stocks. Number in brackets indicate the minimum number of personnel required for the survey.

| Water Body Type | Sampling Gear Used | Sampling Strategy |
|--------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Small streams up to 5 m wide. | 1 hand-held electrode, DC, 50/100 Hz PDC electric fishing, generator supply, wading (3). | Depletion sampling between stop-netted sections. |
| Small rivers 5–15 m wide, pool-pool/riffle topography. | 1 or 2 hand-held electrode(s), DC, 50/100 Hz PDC electric fishing, generator supply, wading (3) or boat-based in deeper river sections (3–6). | Depletion sampling between stop-netted sections, if possible. |
| Small rivers 5–15 m wide, pool topography, greater than 1m deep. | Boat-based, more than two hand-held electrode(s), DC, 50/100 Hz PDC electric fishing, generator supply (3–6), multiple anode boom array (4). | As above. One-catch relative assessment, calibrated sampling. |
| Large rivers and canals, over 15 m wide and greater than 1 m deep. | Boat-based, 2 boats (7–8), more than two hand-held electrode(s), 50/100 Hz PDC electric fishing, generator supply. Multiple anode boom arrays (4), 4–7 kVA generators. Seine netting ('wrap-around' technique) (at least 6). Catch statistics/licence returns. Creel census. Hydroacoustics (2). | Depletion sampling. Calibrated sampling. Relative assessment. Capture-recapture. Depletion or calibrated sampling. Catch effort and trend analysis. Calibrated biomass and density estimates. |
| Large still waters. | As for large rivers, electric fishing and netting in margins only. Gill nets. | As for large rivers. |

fishing survey can be extrapolated to the total area of the system and tentative conclusions drawn about the nature and extent of the stocks of fish within it. Due to seasonal changes in the biomass of a fish stock, species-specific migration periods, and the habitat requirements of specific life-stages, the timing and choice of sampling sites must be considered in detail.

Statistical methods provide alternative means of assessing fish populations in both freshwater and marine environments (e.g. the use of catch and catch per unit effort [CPUE] data, or

mark/recapture experiments). Standardised assessment methods have now been identified (European Standards — EN) for use under the EU Water Framework Directive for defining the ecological status of water bodies (EN 14011, CEN 2002; EN 14962, CEN, 2004; EN 14757; CEN 2005). In many instances, these methods will also be appropriate for addressing questions related to Cormorant-fishery interactions. Techniques for stock assessment in inland fisheries are discussed at length in Cowx (1996) and some of the more common assessment methods are outlined in a little more detail below.

8.2.1 Netting

Both seine nets and gill nets (described above) are widely used for sampling fish populations in fresh water, although trawl nets and fixed nets (e.g. fyke nets) are also used in some instances. Relative changes in fish community structure and population size of those species and sizes caught in the nets can be assessed directly by netting surveys where these are repeated on a regular basis. The data generated through netting surveys can also provide quantitative estimates of fish abundance in sampled areas, for example where repeat (depletion) or mark-recapture surveys can be carried out (discussed in more detail under electro-fishing below). However, netting surveys may often generate more qualitative information, for example in relation to the species and size composition of fish in the catches in a particular water, and data may be restricted to particular species and/or sizes of fish.

8.2.2 Electro-fishing

Electro-fishing is often used for survey work in freshwater, principally in rivers and streams (in saltwater it is impossible to maintain electric fields of sufficient strength due to the high conductivity of the water). When direct electric current is passed through water, a fish within the electrical field will be attracted towards the anode (the positively charged electrode) becoming narcotised temporarily as it nears the anode. Fish exposed to alternating current are stunned by, but not attracted to, the electrodes. The intensity of this effect depends upon the potential gradient to

which the fish is exposed, and larger fish will be influenced more than smaller ones (Murphy & Willis 1996). Stunned fish are then usually removed using hand-held nets and placed in aerated water tubs to recover. Susceptibility to electro-fishing varies among species because of innate differences in anatomy and behaviour, and other parameters such as water turbidity, conductivity and temperature also

affect gear efficiency (Reynolds 1983).

In rivers, sampling is usually carried out at fixed sites delimited by seine or stop nets, man-made or natural barriers, or along designated stretches of a watercourse. The sampling runs may be repeated two or more times at each site to enable depletion estimates to be made (see review by Cowx, 1983). Where



Figure 8.7 Fyke nets hanging up to dry. Photograph— Shutterstock.



Figure 8.8 Electro-fishing with backpack 'shocker' in a narrow, shallow section of river. Photo courtesy of W Hauer.

sections are sampled using a single run, the resulting data will, at best, be semi-quantitative. Alternatively, mark-recapture methods can be used. Catch probability and catchability also need to be taken into account in assessing fish densities using this approach, as these will vary with the species and size of fish and water conditions can influence the results. In general, fish are harder to catch effectively in faster-flowing shallow water and in water deeper than about 2 m. Catch probability describes the depletion rate over successive runs (based on certain assumptions) (Hilborn & Walters, 1992), while the sampler has to estimate catchability. In shallow (wadeable) water bodies the depletion rate should be more than 0.5 in order to fulfil the criteria for calculating fish density after Seber & Le Cren (1967) or De Lury (1947).

Different electro-fishing equipment is available for different habitats and sampling depths. In wadeable

areas (less than 0.7 m depth), boat-mounted electric generators or backpack 'shockers' can be used with varying numbers of anodes according to the width of the stream and the equipment being deployed. In non-wadeable areas, of up to 2 m depth, fishing has to take place from a boat using equipment powered by a generator (CEN 2002).

Large river sections can be sampled using boom-mounted, multi-anode electric fishing equipment, and this can be effective at depths of up to about 2 m. It may be possible to make some assessment of the fish evading capture, although this will be severely constrained in more turbid water. Where sections are sampled using a single run, the resulting data will, at best, be semi-quantitative.

Netting and electro-fishing surveys are more difficult to apply quantitatively at still water sites, particularly larger ones, and at such sites may only provide information

Figure 8.9 Electro-fishing from a boat in a wider section of river.

Photo courtesy of W Hauer.



on such things as species composition and fish growth rates.

8.2.3 Fish traps

Many different types of fish traps can be used to sample fish populations. For example, in rivers, fish traps can be used to provide data for migratory species such as Atlantic Salmon (*Salmo salar*) and sea trout (migratory Brown Trout *S. trutta*, both adults and smolts). However, traps rarely operate with 100% efficiency and it is usually necessary to estimate the trapping efficiency in order to use resulting data quantitatively. This can be achieved by the use of mark and recapture techniques, although even then the efficiency of the trap can vary with environmental conditions throughout the duration of the run and the efficiency of tag or mark detection must also be taken into account. Estimates of Salmonid populations obtained using these



Figure 8.10 A fish trap showing outstretched mesh ‘wings’ that guide fishes in to a central holding compartment. Photo courtesy of W Hauer.

methods may have wide confidence limits attached to them.

Fish traps, and other static fishing gear such as fyke nets, can also be used in slow-moving waters or still water situations to sample fish. However, such gear may be highly selective in the species and sizes of fish that are captured and is unlikely to provide quantitative data on fish population or stock size, or reliable information on species composition.

It should be noted that fish traps can capture non-target organisms, which may then drown within them. In particular, in areas frequented by European otters (*Lutra lutra*), trap mouths may have to be fitted with ‘otter guards’ to prevent the animals entering the traps.

8.2.4 Longlines

Longlines (described in section 8.1.5) can also be used for catching

fish in freshwater, most commonly in large rivers (of more than 2 m depth) and lakes to catch bottom-dwelling species. Longlines are unlikely to provide quantitative data on fish stock size (although may provide an index based on catch per unit effort — see 7.2.6) and may be most useful for obtaining information on species composition (CEN 2004). However, it is unlikely that all species (and/or sizes) of fish in most habitats will have an equal probability of being caught. Measures should always be taken to prevent accidental catches (and death) of non-target organisms.

8.2.5 Electronic fish counters

Fish counters are mainly used for monitoring runs of migratory adult Salmonids (trout and salmon). Their efficiency depends upon the reliability and design of the apparatus and appropriate positioning of the facility. Properly set up and validated, such counters

are capable of providing an accurate estimate of numbers of adult fish returning to a river system. However, sub-sampling of the catch is often required to accurately apportion the counts by species or between particular age groups.

8.2.6 Catch records and CPUE data

Catch and Catch Per Unit Effort data may provide a useful index of abundance for freshwater fish stocks (see review by Cowx 1991), particularly where these exist as a reliable time series. The catch taken by fishermen/anglers also provides a direct measure of stakeholder satisfaction. In some large freshwater bodies, and for certain particularly high value species such as Atlantic Salmon, long-term catch data are available. However, the ability to compare such data across years requires some knowledge of associated fishing effort. Even assuming reasonably accurate catch data, the issue of relating fish catch

to fish population or stock size may need to be considered. In general terms, a larger stock size would be expected to result in better catches, and such relationships have been demonstrated for many species. However, a consistent catch/stock relationship cannot be assumed, and exploitation rates can vary between fisheries, between species and over time.

Data from angling competitions ('matches') where good catch records are kept, and from questionnaire surveys of recreational anglers can also be successfully used to evaluate some fisheries, particularly larger bodies of still water and wide, deep rivers where most other techniques are ineffective. Such methods can provide a cost-effective method of monitoring long-term changes in a fishery, potentially over large areas or long stretches of rivers. The resulting data generally yield information on changes in fish community structure (or at least that part of it that is caught routinely) and relative abundance, rather than any quantitative measure of stock size *per se*. However, match catches can be employed in mark-recapture exercises to yield quantitative estimates of fish densities.

8.2.7 Mark-recapture methods

Overall fish numbers in a specific water can be estimated by giving a sample of the fish population within it a distinguishing mark (or tag) and releasing them back into the original population. The ratio of marked to unmarked fish subsequently recaptured can be used to estimate the size of the



Figure 8.11 Fish can be marked with tags (top) or with injected coloured dye (above). Photos courtesy of W Hauer.

fish population (assuming certain underlying criteria are satisfied). The method can be applied equally to migratory species (e.g. for assessing runs of adult Salmon or smolts), or for non-migratory trout and other freshwater fish within a defined area.

When arriving at population estimates using this method it is assumed that: marked fish are representative of the whole

population, they are randomly dispersed within it, the marking procedure does not affect the behaviour or catchability of the fish, and all fish in the population have an equal probability of recapture. Furthermore it is assumed that there is no immigration or emigration, recruitment or mortality over the sampling period and that all marked or tagged fish caught are detected and reported.

8.2.8 Hydroacoustics

Hydroacoustic techniques are increasingly being used in freshwater situations, particularly on larger water bodies where other fish-sampling methods may be more difficult to apply (Winfield *et al.* 2009). Such methods need to take account of variability in fish distribution, since this is known to change both diurnally and seasonally for many species. In fresh water, higher fish densities tend to be recorded at night and in the summer or autumn months than at other times of day or season, presumably as a consequence of changes in fish behaviour (Winfield *et al.* 2007).

8.2.9 Fish production data

In the case of both intensive and extensive fish farms, managers will typically have a reasonably robust knowledge both of fish numbers at various stages of production and of the expected harvest levels. In addition, regular monitoring (e.g. of the quantity of food consumed by the fish) may provide a fish farmer with an indirect estimate of fluctuations in a fish 'population' (based on experience of the expected consumption rates for particular species and sizes of fish under particular conditions).

8.3 Problems in estimating the abundance of fish

Commonly, the results obtained from fish stock assessment techniques do not provide an estimate of absolute abundance of the fish stocks present, but they may give an index of stock abundance. Nevertheless, they can

still be used to identify trends and alert fisheries managers to potential problems. There are a number of inherent problems associated with sampling fish stocks that need to be borne in mind and some of the most important are discussed below.

8.3.1 Fish distribution

Fish may not be evenly or uniformly distributed throughout a water system, either in time or in space. For example, many species aggregate in shoals, or may be associated with particular habitat features, and other species undergo seasonal migrations. Such discontinuous patterns of distribution can make stock assessment particularly difficult and mean that stock estimates (e.g. numbers per unit area or unit volume) vary both temporally and spatially.

8.3.2 Gear Selectivity

The efficiency (or selectivity) of nets and almost all other fish sampling gear invariably gives rise to sampling errors. This can be the result of the positioning of gear (e.g. on the bottom or at the surface), whether it is moving or static, and also a consequence of features of the gear itself (e.g. net mesh-size and hanging arrangement). Nets usually only catch a certain group of species, or a particular size-range of fish, and smaller fish (individuals and/or species) are commonly under-represented in fish biomass estimates. This may have implications for researchers and fisheries managers, as fish recruitment is very variable and information on year-class strengths may therefore be missed in many sampling programmes. In addition,

trawl surveys, more commonly used in large, deep rivers and estuaries, may positively select for bottom-dwelling species and mesh selectivity may also apply.

In freshwater, electro-fishing becomes progressively less efficient as the area and depth of the sampled water body increases. This technique is also selective for larger individuals since the intensity of the effect depends upon the potential gradient to which the fish is exposed. The recent development of boom-mounted multi-electrode electro-fishing equipment has improved the efficiency of sampling fish populations in larger rivers, particularly for smaller shoaling species. However, sampling stillwater systems in this way remains problematic. In such situations, electro-fishing tends to be more efficient at catching larger, territorial species such as trout than for catching small, shoaling species.

8.3.3 Gear avoidance behaviour

Some species of fish are more adept than others at avoiding capture, or are not adequately sampled by certain methods. The assumptions underlying electro-fishing, seine netting, depletion, and mark-recapture estimates may be violated by initial (or acquired) gear avoidance behaviour by fish.

8.3.4 Stocking

Assessing fish stock sizes, in the context of evaluating the impact of Cormorant predation for instance, also necessitates consideration of the role that stocking might play in influencing fish population structure and size. Stocking is

carried out routinely at many freshwater sites in order to enhance stock levels, commonly for angling purposes. However, as discussed in chapter 6, there are concerns over such stocking in relation to ecological imbalance and the possible effects on fish community structure. There is also the possibility that stocked fish may be more vulnerable to predation than wild conspecifics, since although anti-predator behaviour in fish is in part based on inherent predisposition, this is also acquired through learning during a fish's lifetime (Magurran 1990a and b, Kieffer & Colgan 1992).

8.3.5 Variability over time

Natural variability in estimated fish numbers (from any of the

techniques described above) can be substantial over time. For example, Figure 8.12 illustrates variation in Brown Trout density at the same small stream site over several consecutive years. This dataset clearly indicates differences in fish abundance (numbers per hectare) both among seasons and between years (Haunschmid 2004). The stream section was easy to survey and had a high catch probability, and the resulting estimates are considered to reflect the natural variability in fish numbers at this particular site.

Statistical sub sampling from the data presented above (Figure 8.12) indicates that calculating fish abundance from any one (randomly chosen) sample out of six leads to a mean difference of more than 20%

in comparison with the mean value derived from the full six years of sampling (Figure 8.13).

Ideally, therefore, data sets should be large and cover extended periods so that natural variability in the fish population estimates can be quantified from them. Only then is it possible to explore what other factors may be responsible for unexpected changes in fish abundance as measured through standard sampling techniques.

8.3.6 Reliability of data

Estimates of fish stock abundance are frequently influenced by a range of potential confounding factors and fish density estimates often have large levels of associated statistical error. This

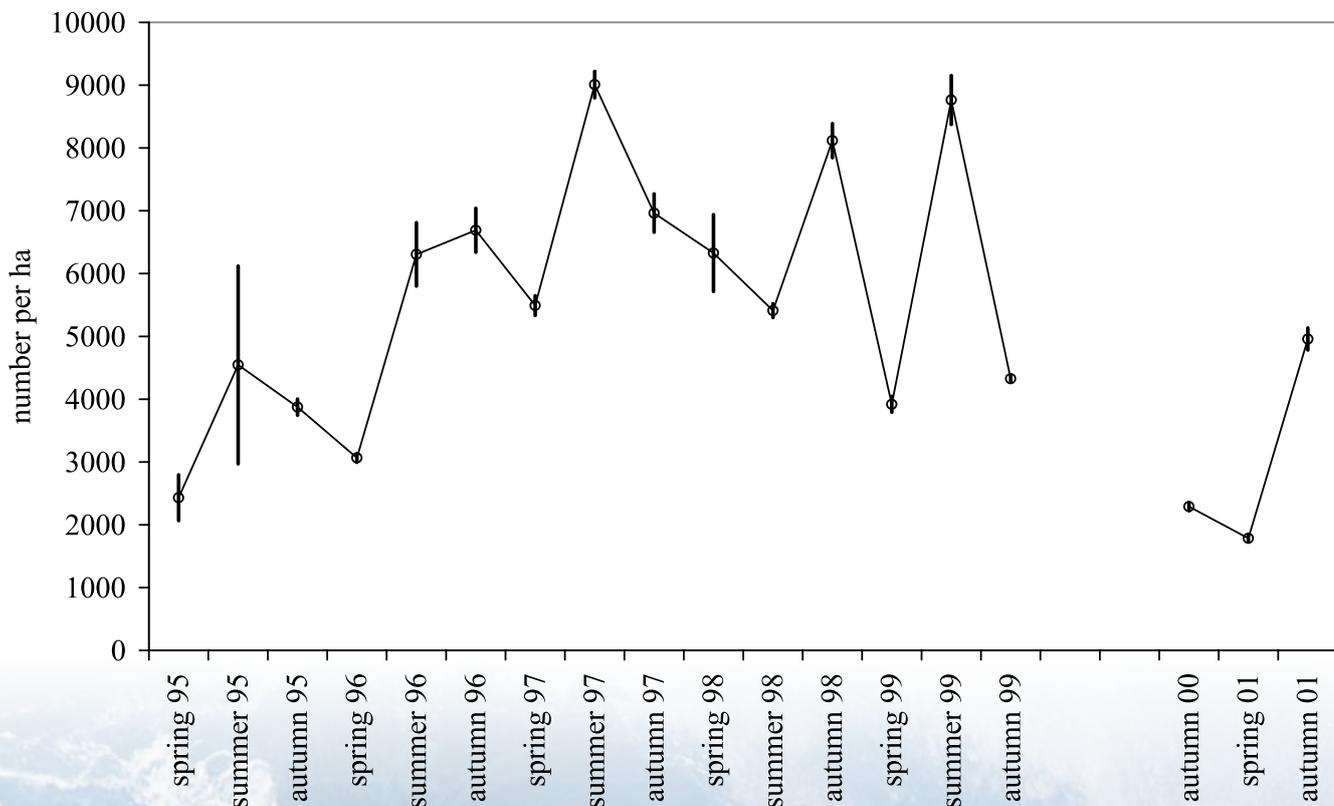


Figure 8.12 Density of Brown Trout in a small stream estimated from repeated standardised sampling over a 6-year period.

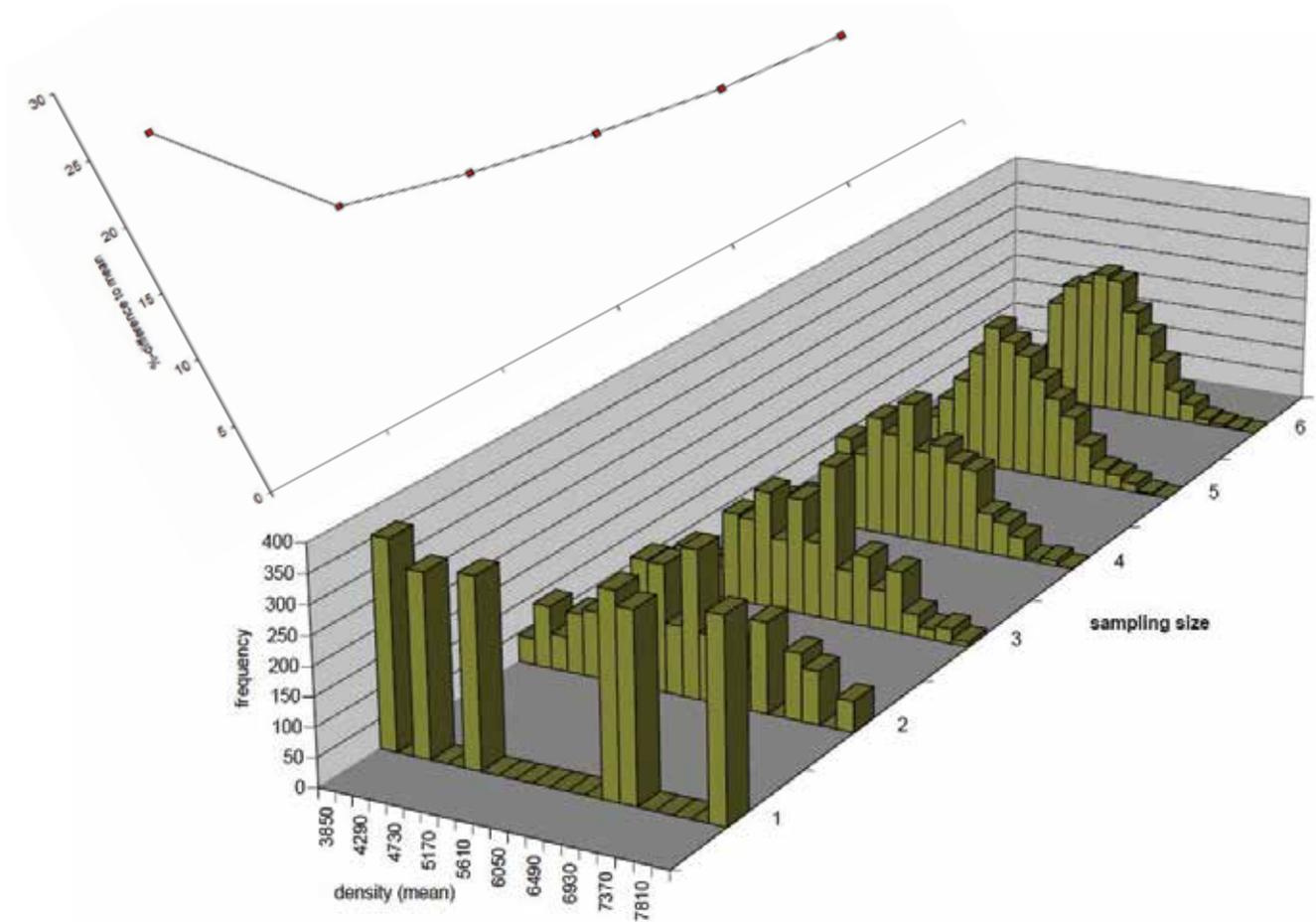


Figure 8.13 Differences in the estimated density of Brown Trout in relation to sample size.

needs to be recognised when interpreting results and using these in estimating levels of Cormorant impact for example (see chapter 10). In this context, one additional piece of data that can

be obtained from the fish sampled for stock abundance estimates is the proportion of individuals that are wounded or damaged by bird predators such as Cormorants (see chapter 9). Such wounds can be

specifically related to particular predators and may provide further information on the potential impact of predators on their prey.

9 INDICATORS OF CORMORANT DAMAGE

H Engström, P Musil and I C Russell

The wounding of fish by Cormorants is widely reported in the scientific literature and there is evidence that wounding rates and bird densities are correlated (Klee, cited in Russell *et al.* 1996). Although Great Cormorants are known to be vectors for various fish parasites and possibly also fish diseases (Beveridge 1988), the extent to which the birds might influence parasite infestation rates or disease incidence in fish (and ultimately fish population size) is unclear. Behavioural changes associated with Great Cormorant presence, and reduced catchability of fish, are widely reported by fishery managers (Callaghan *et al.* 1994, Carss & Marquiss 1995) but once again it has not been possible to quantify the impact of behavioural or stress responses at the fish population level.

9.1 Wounding of fish

In addition to consuming fish, predators such as cormorants are commonly reported to injure or damage fish, as a consequence of capturing some individuals that subsequently escape. Such wounded fish have been reported from both fish farm operations and the wild. Damaged fish bear marks consistent with having been hooked

and grasped by the beak of the bird, and these marks are characteristic of specific bird predators.

9.1.1 Cormorant

The Great Cormorant has a large powerful beak with a strong hook, which produces a characteristic deep triangular wound or slash on one side of the fish (often puncturing the body wall), and an area on the other side where scales have been scraped off by the lower mandible (van Dobben 1952, Ranson & Beveridge 1983, Carss & Marquiss 1991, see also Figure 9.1). In other cases, fish may be gripped tightly on the head (Carss 1990).

9.1.2 Heron

Fish injured by herons (e.g. Grey Heron *Ardea cinerea*) tend to have characteristic parallel wounds caused by the edges of the bird's bill. Such fish are often damaged on both sides often around the

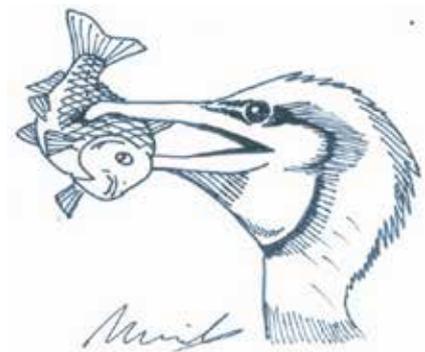


Figure 9.1 Typical wounds caused by Great Cormorant.

Photo courtesy of W Hauer. Photo inset courtesy of J Kortan.

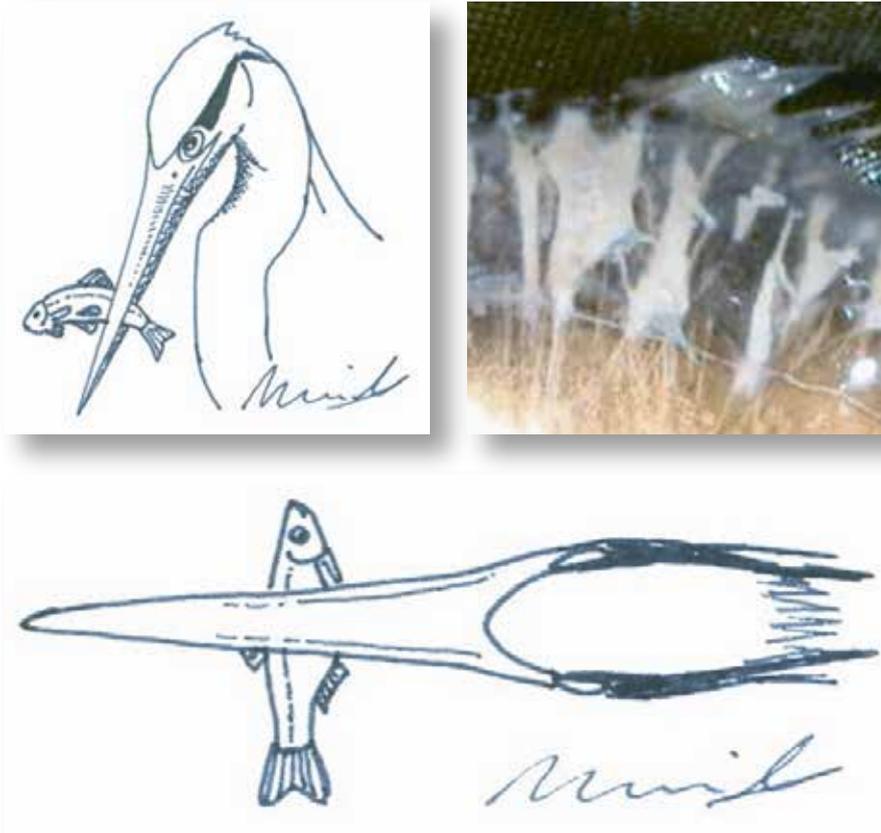


Figure 9.2 Typical wounds caused by heron. Photo courtesy of J Kortan.

operculum (gill cover) region, as the fish are generally attacked from above. The whole fish body may be covered in such marks if the heron has manipulated the fish for some time prior to it being dropped (Carss & Marquiss 1991, see also Figure 9.2). In some instances, larger fish may have wounds consistent with having been stabbed by the heron's bill.

9.1.3 Shag

The Shag (*Phalacrocorax aristotelis*) is similar to the Great Cormorant in physical appearance, but is a smaller bird and has a correspondingly smaller beak which lacks the strong hook of the Cormorant. The mandibles are finer and their edges more parallel. The resulting wounds are smaller than those made by the Cormorant, and

although the beak tip occasionally punctures the skin, the resulting wounds are usually less severe than those caused by Cormorants (Carss & Marquiss 1991).

9.1.4 Gulls

Based on observations at some fisheries in Northern Sweden, gulls (*Larus* spp.) may also inflict wounds on fish held in cages (H. Engström, unpublished). Marks caused by gulls seem to be difficult to tell apart from damage caused by Cormorants, although gulls lack the hooked upper mandible and are unlikely to puncture fish in the same way. No detailed studies have yet been carried out on the damage to fish caused by gulls.

The wounds suffered by fish vary in their severity. Damage to the

epidermis and scales makes fish more susceptible to secondary infections, such as bacteria and fungi, and this can lead to the breakdown of body tissues (Carss & Marquiss 1991). Some injured fish may die from the infections or wounds, but the extent of such mortality is difficult to quantify.

9.2 Damage at fish farms

At fish farms, scarred individuals may be unmarketable and thus represent a direct economic loss. Surveys at Salmonid cage farms in Scottish lochs, where Great Cormorants appear not to enter cages but attack fish through the netting (Carss 1993), have indicated relatively low levels of fish with Cormorant damage (<1% of Rainbow Trout *Oncorhynchus mykiss*, mostly 5–9 cm in length). However, the frequency of wounding depends on fish age, size and species, and on whether fish are held in net cages, ponds or lakes (Beveridge 1988). Studies in the Netherlands have recorded the occurrence of 'many' wounded fish at a large Carp *Cyprinus carpio* culture site where up to 500 Cormorants fed (Moerbeek *et al.* 1987). In Denmark, 32–45 cm Rainbow Trout placed into pound nets (fish traps) suffered a 3.5% damage rate in the first 8 hours (Dieperink 1993).

Data documenting the relationship between the body size of Carp and the relative levels of damage caused by Cormorants at Carp ponds are available from Oberlausitzer Fischteiche (Saxony, Germany). The highest levels of damage were recorded in Carp with a length of 26–35 cm

Table 9.1 The number of Carp injured by Cormorants in relation to fish body length. Samples of 200 Carp were taken from 20 different stocks in Saxony (Oberlausitz). Injuries are presented as percentage of all samples (Seiche & Wünsche 1996).

| Carp length (cm) | Small injuries | Moderate injuries | Large injuries | Total injuries |
|------------------|----------------|-------------------|----------------|----------------|
| 5–10 | 3.2 | - | - | 3 |
| 11–15 | 12.0 | - | - | 12 |
| 16–20 | 6.1 | 0.8 | 0.2 | 7 |
| 21–25 | 10.6 | 4.1 | 0.5 | 15 |
| 26–30 | 14.9 | 1.9 | 1.2 | 18 |
| 31–35 | 16.7 | 2.8 | - | 20 |
| 36–40 | 12.1 | 0.4 | - | 13 |
| 41–45 | 4.4 | 1.5 | - | 6 |

(Seiche & Wünsche 1996). This probably reflects the fact that smaller fish (<25 cm) are more likely to be manipulated and swallowed successfully and thus less likely to escape, while larger fish (>40 cm) are mainly too large for Cormorants to attack. However, this finding probably to some degree also reflects prey-size selectivity — with smaller fish probably being the optimal size for foraging Cormorants. For example, evidence from South Bohemian

fish ponds (Czech Republic), where ponds contain various age cohorts of Carp, indicates that Cormorants selectively use fish ponds containing one-year old Carp (10–20 cm in length). Similarly, fish of this size were also recorded more frequently in their diet (Musil *et al.* 1995, Musil & Janda 1997).

Researchers in Saxony have found a strong relationship between the proportion of Carp that are injured



by Cormorants and the body length of the fish (Table 9.1). Most (50%) injured Carp are in the length range 26–40 cm. It is thought that smaller fish are swallowed with few escaping, whilst larger fish are less commonly hunted by the birds.

9.3 Damage to wild stocks

Levels of fish-eating bird damage in different wild stocks are summarized in Russell *et al.* (1996). For example, various studies on lakes and rivers in Germany and Switzerland have noted wounding rates in the spring (after winter Cormorant flocks depart) of 10–25% (sometimes 50–60%) among species such as Grayling *Thymallus thymallus* (see Figure 9.4), Brown Trout *Salmo trutta*, Whitefish *Coregonus* spp., Chub *Leuciscus (Squalius) cephalus* and Pike *Esox lucius* (Staub *et al.* 1992, Staub & Ball



Figure 9.3 Typical imprint of Cormorant's beak on a two-year-old ('mirror') Common Carp. Photo courtesy of J Kortan.



Figure 9.4 Whitefish (*Coregonus* spp.) injured by Cormorant.

Photo courtesy of W Hauer.

1994). Other studies from this area reported that some Grayling showed healed wounds from a previous winter's attack, and that levels of wounding were not considered to adversely affect the species' population dynamics (Suter 1995).

On a river in North West England, 2–18% of Dace *Leuciscus leuciscus*, Roach *Rutilus rutilus* and Chub had marks resulting from Cormorant attack (Davies, cited in Russell *et al.* 1996). Damaged fish were found to be significantly larger than undamaged ones, and the proportions of stock damaged

were significantly higher for Chub than for Dace. In Denmark, experiments in coastal pound nets (where fish were constrained within fish traps) indicated that 13–35% of trapped Cod *Gadus morhua*, Herring *Clupea harengus* and Flounder *Platichthys flesus* were wounded by Cormorants during each tidal cycle (Cornelisse & Christensen 1993).

Other authors have also noted higher wounding rates among some species than others, for example Whitefish caught in pound nets. This finding possibly reflects behavioural differences

between fish species (Engström 1998). Habitat use and the conspicuousness of different fish species may also affect encounter and wounding rates, with 'non-cryptic' species likely to be more frequently attacked than 'cryptic' species. The toughness of fish skin may also affect the severity of wounding. For example, some fish species like Eel *Anguilla anguilla*, which are common prey of Cormorants at certain times, rarely appear to carry open wounds. Wounding rates are also likely to vary with the foraging and prey manipulation experience of the bird, with higher wounding rates likely to occur with inexperienced immature birds.

Ultimately, fish damaged by predators such as Cormorants are often conspicuous in catches and levels of damage can be relatively high for particular times and places. It is also possible that wounded fish are more likely to be caught in fish samples and thus their true abundance in the population is overestimated. The proportion of damaged fish which survive their injuries is not known, but clearly the most severe wounds are likely to be fatal and even less serious wounds can cause direct economic losses as such individuals are often unmarketable. At the population level however, the effects of such damage (or those of secondary effects through increased susceptibility to disease) are currently poorly understood.

10 ATTEMPTING TO INTEGRATE CORMORANT AND FISH DATA

D N Carss, R Haunschmid, R Parz-Gollner, I C Russell and J Trauttmansdorff

10.1 Introduction

This final Chapter of the **INTERCAFE** Field Manual is devoted to the subject of scientific attempts to quantify Cormorant impact on fisheries — through the integration of both Cormorant and fishery data obtained by researchers often using the methods outlined and discussed previously in Part One and the first section of Part Two, respectively. Whilst this chapter focusses on the viewpoint of the ecological researcher, and thus may be of limited practical value to most fisheries stakeholders or managers, it is hoped that it will also shed some light on the issues facing biologists addressing Cormorant predation issues.

Before discussing the integration of Cormorant and fishery data and predator-prey relationships more generally, it is important to take some time to consider how Cormorant ‘impact’ can be understood or interpreted by different people, depending on their often diverse values, attitudes and expectations. Impact clearly means different things to different people. In some circumstances (e.g. biological or economic), it may be possible to attempt to measure impact quantitatively. In

others (e.g. when the understanding of impact relies more on human attitudes and values (see for example chapter 10 of Marzano & Carss 2012), it will be necessary to assess impact qualitatively. It is important to realise, in this case, that both quantitative and

qualitative approaches are to be taken seriously and, indeed, a qualitative approach may yield in some cases a more accurate assessment of impact on social grounds as experienced by fisheries stakeholders undertaking their commercial and/or recreational

In managing fishery resources, managers need to consider the state of the resource and the provision of fishing opportunities. Satisfactory fishing depends on the presence of healthy fish in appropriate numbers; regulation of fisheries cannot be considered in isolation from the ecosystem of which fish are a part.

The word ‘fishery’ has a range of meanings, which are important in understanding the Cormorant-fishery conflict and the potential ‘impact’ of the predators on their prey. ‘Fishery’ can mean:

- The ecosystem including its fish, whether or not these are fished for (to ecologists).
- The enterprise managed (to fisheries managers).
- The place where they fish (to fishermen/anglers).
- The sphere of activity covered by the relevant law (to policy makers).

Thus, conflicts (and ‘impact’) might therefore be viewed at:

- The ecosystem level – as changes on fish stock size or species composition (which may operate over the long-term), and
- The ‘enterprise’ level – as reduction in fishery income, and/or
- The resource/individual level - as reduction in amenity value (both of which may be felt directly in the short-term).

Text Box 10.1 An example of spatial scale when considering Cormorant impact on fisheries (modified from Russell 2006).



Figure 10.1 Harvesting fish from a Carp pond – a relatively small ‘closed’ system. Photo courtesy of INTERCAFE.

activities. It is also necessary to think about the ‘frame’ within which knowledge of Cormorant impact and associated bird and fishery data are to be interpreted. Clearly there are both spatial and temporal elements to this but there are also a variety of scales over which impact at a fishery (a term with a range of meanings) can be considered (see Text Box 10.1).

The issue of temporal scale is important because much of what is discussed in relation to fish populations (e.g. compensation, lack of population effects) occur over the long-term, probably on a generational scale. However, many conflicts with fisheries occur over short timescales (i.e. weeks/months). For example, there is widespread agreement that Cormorants often forage very efficiently at a site and then, once prey becomes relatively scarce, move on to an alternative one. Thus, one might well expect to see short-term impacts such as depressed

catches even if a population bounces back in the longer term. From a biological perspective, long-term population resilience to predation might be equated with no serious damage, but this view is unlikely to be shared by fishery managers or owners, recreational anglers or fish farmers whose catches (income or amenity values) are depressed in the short-term.

In most circumstances, the term ‘impact’ is implicitly used to describe a situation where Cormorants are consuming sufficient fish in a system so as to affect it negatively from a human perspective. This almost invariably equates to a reduction to fish catches, fish value, or to a specific portion of that catch (e.g. a particular species or age/length class of individuals). However, choosing the ‘correct’ spatial scale within which impact is both biologically meaningful and meaningful to specific fisheries stakeholders may not always

be easy. Smaller water bodies (particularly ‘closed’ ones within well-defined spatial limits) and the fish in them often react more quickly to changes in environmental factors (both biotic and abiotic) than do larger ones that can usually buffer any effect to some degree at least. It could be similarly argued that Cormorant predation is more likely to have an impact on a particular fishery or fish species operating within a smaller water body than within a larger one (or a series of similar habitat patches spread throughout the landscape).

Furthermore, within this concept of ‘frames’, careful consideration must be given to the criteria upon which any impact will be judged. Obviously, if there is an impact, it should be measurable — but what should be measured? How? By whom? Over what period of time? What information would be required to demonstrate impact? These are all pertinent questions, though some may feel they are just adding unnecessary complexity to something that is obvious — that Cormorants do have negative impacts on fisheries and thus should be controlled or managed to reduce this. Nevertheless it should be acknowledged that there is often serious disagreement over whether or not Cormorants cause an impact at fisheries precisely because the term itself means different things to different people who use different knowledge bases to quantify it.

10.2 Interpreting understandings of Cormorant ‘impact’ at fisheries

One very practical way of exploring the complex potential impacts



Figure 10.2 Like almost all European wild birds, the Great Cormorant is protected under the Birds Directive.

Photograph — Shutterstock.

of Cormorants at fisheries is to consider it from the perspective of legislation. This is a useful approach because the derogation facility within the legislation, requires consideration of the ‘damage’ that Cormorants can cause and, as such, allows us to think about ‘impact’. Indeed to many people the terms ‘serious damage’ and ‘impact’ have become synonymous in their discussions of Cormorant-fisheries conflicts.

At its heart, the general pan-European scheme of protection for Cormorants (like almost all other wild birds on the continent, and in Great Britain and Ireland) is based on the Birds Directive (79/409/EC). Key provisions of the Directive in relation to Cormorant conservation and management are shown in Text Box 10.2 (see also chapter 8 of Marzano & Carss 2012).

As with all European Directives, Member States are given certain flexibility about the way in which the Birds Directive’s binding obligations are achieved. Put very simply, Member States are signed-up to the obligations of the Directive but the precise route for getting there, constrained to some degree, is left partly to the discretion of individual Member States. In terms of the management of Cormorants across Europe (and, by implication, the rationale behind the necessity to undertake management in the first place (i.e. their impact or damage to

fisheries), one very important outcome of this approach is the diversity of interpretations across Europe. This is particularly true in the case of derogations whereby Member States request permission to manage the species. They need to consider carefully what constitutes ‘serious damage to fisheries’ and ‘no other satisfactory solution’ for instance, and there appear to be differing interpretations.

Prior to the REDCAFE and INTERCAFE projects, attempts to resolve these problems relied largely on the work of

Article 1 — the Directive relates to the conservation of all wild bird species.

Article 2 — Member States take requisite measures to maintain populations at levels that correspond to ecological, scientific and cultural requirements... taking account of economic and recreational requirements.

Article 3 — the general duty of habitat/biotope conservation.

Article 4 — specific habitat conservation measures, especially Special Protection Areas for Annex I (i.e. considered endangered and requiring special conservation measures — does not apply to the Great Cormorant) and migratory species (e.g. the Great Cormorant), especially regarding wetlands.

Article 5 — establish a general system of protection, prohibiting in particular deliberate capture and killing, disturbance, destruction of the nest or the taking of eggs.

Article 8 — prohibited methods of killing and capture.

Article 9 — derogation scheme of Directive, where no satisfactory solution is found and for specific reasons including ‘to prevent serious damage to fisheries and water’ and ‘for the protection of fauna and flora’.

Article 10 — encouragement of research.

Text Box 10.2 Key provisions of the EC Birds Directive in relation to Cormorant conservation and management.



Figure 10.3 Fish, and the fisheries they support, usually have very strong economic elements — be they commercial or recreational. Photographs— Shutterstock.

biologists — because biological understanding has fundamental importance (Carss *et al.* 2009). Yet within the biological community there has long been debate surrounding the question of whether fish-eating birds seriously damage fisheries (e.g. Marquiss & Carss 1997). Several major reviews of the scientific literature have concluded that, despite many studies, there are few instances where scientists have demonstrated long-term, population level effects of Cormorant impact on fish populations, other than at relatively ‘closed’ simple systems such as fish farms, ponds, or within some heavily modified running waters. However, this lack of biological evidence is recognised not to be necessarily because birds rarely affect fisheries, rather it reflects the

practical difficulties in establishing any effect incontrovertibly. Indeed, in the light of seeing large numbers of birds at their fisheries consuming large numbers of valuable fish, the onus placed on fisheries managers and anglers to demonstrate or prove ‘serious damage’ from a biological perspective before being granted a derogation to kill birds has been criticised for putting these stakeholders at a disadvantage (Marquiss & Carss 1997). Case studies in the UK (e.g. Feltham *et al.* 1999) indicated that Cormorant predation at some sites may be high enough to cause a decline in the fishery, but not at others where other factors may be more significant. This study concluded that the impact of Cormorants on inland fisheries was a problem at specific sites rather than a general

problem. Thus the quantification of impact from a biological perspective has to be site-specific.

From a purely biological perspective, there are well-documented and acknowledged problems of quantifying Cormorant impacts generally, and ‘serious damage’ specifically (see also Russell 2006). However, the derogation procedure is also ‘intended to prevent damage (i.e. it is not a response to already proven damage)’ and can require a ‘reasonable basis for concluding that damage will be serious in the absence of action’. Thus while offering the opportunity to manage Cormorants without prior proof of damage, the issue of what constitutes ‘serious damage’ is still unclear, but is expected to involve some subjective evaluation.

Furthermore, the derogation also ‘infers an economic interest’ and impact is very often thought of in economic terms by those affected by Cormorants. Unfortunately, while the economic issue may appear easier to quantify than a biological impact, relatively few clear data appear to be available. Indeed, the REDCAFE project specifically explored the reasons for the non-disclosure of relevant financial information within the fisheries sector. This may well be, in part at least, because there are no clearly-defined criteria for measuring impact and so there are no comparable economic data. However, the factors affecting fishery economics are also complex and Cormorant-fishery conflicts rarely, if ever, occur in isolation from other factors. Similarly, **INTERCAFE** had little or no access to financial information that would irrefutably demonstrate that Cormorants were the direct cause of financial losses to a fishery, other than at fish farm sites and small, enclosed recreational fisheries. Again, this does not mean that Cormorants are not capable of causing a financial loss, but merely that the economic data relating to fish losses caused directly by Cormorants have not been collected or collated, or are not readily available, and other possible related losses (e.g. reduction in amenity value or licence sales) are equally difficult to quantify.

There is a growing body of evidence (see Carss *et al.* 2009) that, regardless of the availability of biological and/or economic data, the impact of Cormorants on fisheries is believed to be great in some situations. Indeed the **INTERCAFE** project documented numerous occasions where fisheries



Figure 10.4 Teasing apart the influence of predation from other sources of fish mortality is not an easy task: predation, pollution, habitat modification. Photographs—Shutterstock.

stakeholders stated very strongly that the birds undoubtedly had a serious impact on their fishery, and numerous important social and cultural issues have been discussed in relation to this (see for example Carss *et al.* 2009). Given **INTERCAFE**'s generally integrative ('relativist') approach

to biological, economic, social and cultural perspectives in relation to Europe's Cormorant-fisheries conflicts (see also Marzano & Carss 2012), it is impossible to argue against the validity of many of these socially- and culturally-derived claims of Cormorant impacts and these claims must be taken seriously.

Clearly, a purely biological approach is usually inadequate to the task of trying to address the Cormorant-fisheries conflict in full. Similarly, although economic interests are frequently cited in relation to the damage and impacts that birds have on fisheries, clear economic data *per se* are generally inadequate too.

Although notoriously hard to define, terms such as ‘serious damage’ are clearly opaque and there seems a genuine need across Member States to clarify them as much as possible. The purely biological or economic approaches to determine impact are often

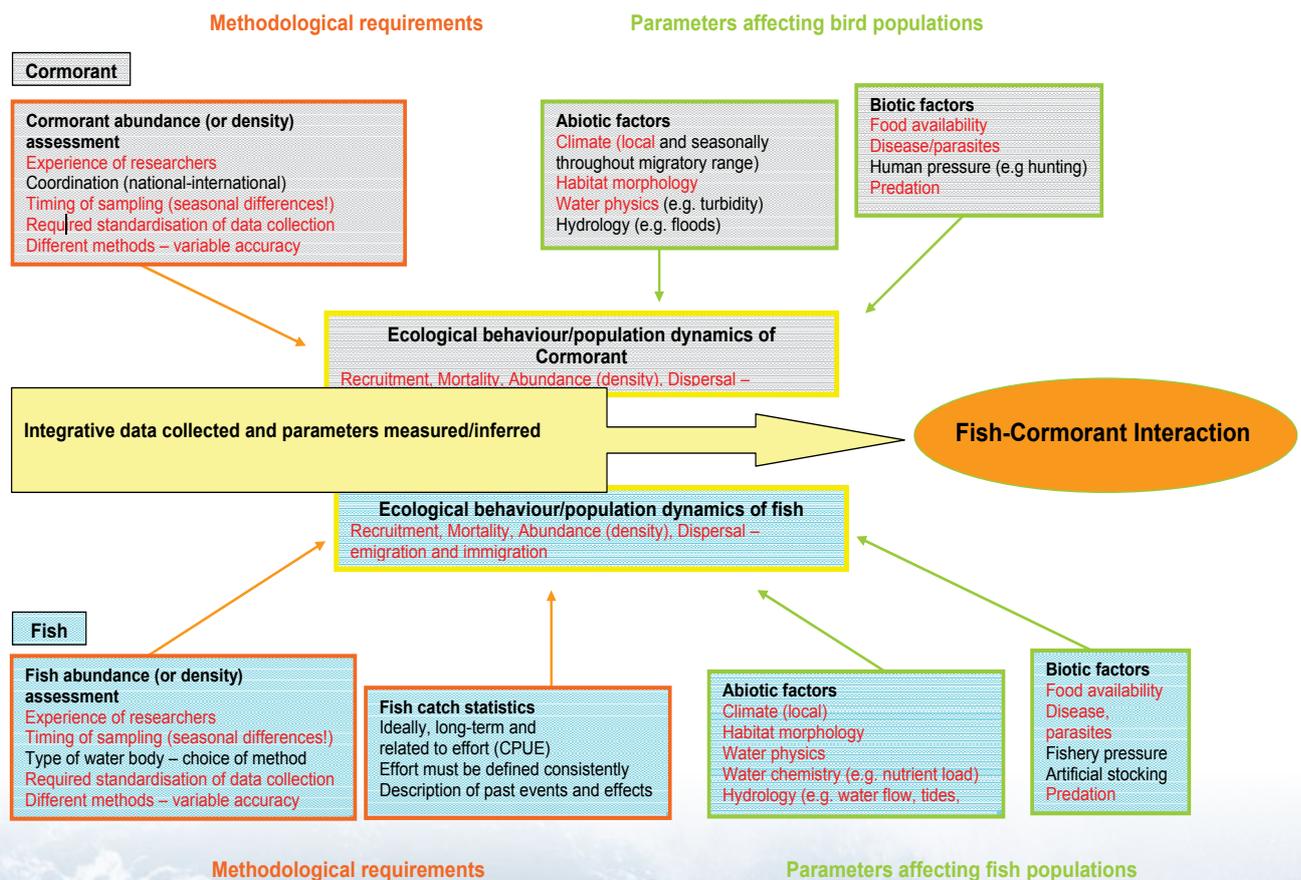
inadequate and so consideration of broader environmental ‘values’ is necessary. For instance as habitat restoration projects continue there may be conflicts of interest over particular species. When these species are scarce there is little problem but when they become abundant (and perhaps prey on other species of conservation value) how is conservation (or management) to be prioritised?

Thus, in keeping with the wording of Article 2 of the Birds Directive, a more holistic approach to the issue of quantifying Cormorant impact should almost certainly include ecological, scientific and

cultural requirements as well as economic and recreational ones in some justifiable and fair manner. This multidisciplinary perspective should also be borne in mind when considering Cormorant ‘impact’ as explored primarily from an ecological perspective in the present chapter.

10.3 Introduction to the ecological perspective

As a synthesis, this final chapter explores the inherent difficulties in integrating both Cormorant and fishery data obtained by researchers. It also aims to discuss



Methodological requirements for data collection and parameters affecting the ecological behaviour and population dynamics of Cormorants and fish. This theoretical sketch diagram illustrates the complexity and breadth of Cormorant-fish interactions.

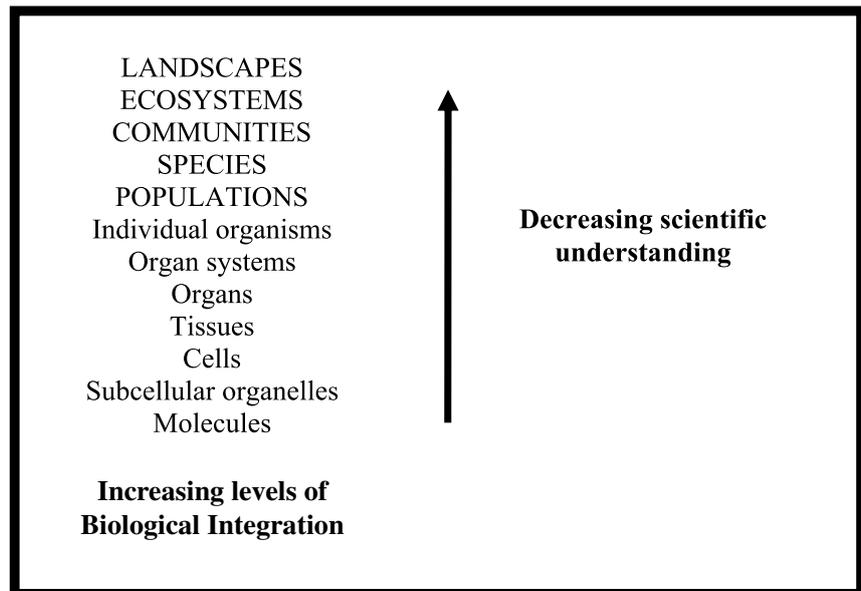
Researchers recognise (at least) twelve levels of biological integration, each with its own separate and distinct series of attributes and methodological problems. The study of ecology is concerned with the top five (upper case) levels. As shown on the right, as we 'progress' from individual organisms, through each of the ecological levels, our scientific understanding decreases. The reasons for this are not hard to understand — they include the increasing complexity of these ecological levels and the difficulties involved in collecting and analysing rigorous quantitative data on them.

Text Box 10.3 Levels of biological integration (based on Krebs 2001, p10–12).

some of the main interdependencies between these data sets.

When discussing two different populations and their associated, inter-related systems, there are many more environmental factors than just the Cormorants and their prey. These factors may be 'biotic' (i.e. biological) or 'abiotic' (non-living, usually physical and chemical) and fit together in a complex, dynamic way, influencing both the results of sampling efforts and interpretations of these results. It seems very rare that the cause of any impact on a fish population is easily identified and that it is caused by a single factor (though a pollution incident in a river or lake is an example of this).

As discussed earlier, great care is needed to collect rigorous ecological data at the population



level for either Cormorants or fish species (see, for example, the methodological requirements boxes in Figure 10.1). Similar care is needed when interpreting such datasets, particularly when Cormorant and fish data are combined to infer something about the impact of the predator on the prey. For example, the diagram on the previous page shows that key biotic and abiotic factors can affect both Cormorants and fish and suggests that the 'system' has the potential to be highly dynamic. This dynamic system deals with two very different organisms that have different demands on habitats, exhibit different behaviour, and have very different distributions in both space and time. The methodological requirements and key parameters affecting the populations of Cormorants and fish highlighted in red reflect both similar methodological issues to be considered by researchers and also those environmental factors that influence both predators and their prey (but often in very different ways).

Though far from complete, this sketch conveys the breadth and scales required of scientific information in order to define and begin to quantify any ecological relationship. Many terms used in the diagram represent a network of different factors, often interacting with each other. For instance, fish abundance can be influenced to a great extent by fish mortality. This mortality is the sum of all deaths in the fish population regardless of their cause, and so includes things like harvest of adult fish by humans, starvation of fry as they compete for space in a habitat, predation, those dying through diseases or parasitism, and deaths caused by one or more abiotic factors. Clearly, it is a major challenge for researchers to quantify the relative proportions of each of these causes of mortality, to tease apart the mortality caused by predators, the proportion of this that is caused by Cormorants and the ultimate effects of this portion of overall mortality on the fish population (stock) or resulting catches. A key scientific issue here is whether, in the system

under consideration, the different mortality factors are additive or whether compensatory factors operate. In other words, whether different mortality factors are cumulative, or whether when one factor increases another decreases. In the latter instance, mortality by predators may be compensated for if fewer individuals die later on due to starvation or competition, or if the growth rate of surviving individuals increases.

The type of the water body also influences the complexity of the system. As discussed elsewhere in the Field Manual, the methods available to researchers to study both Cormorants and fishes become less accurate as the size of the system under investigation increases. Similarly, as these systems become increasingly complex with increasing geographical area, so our scientific understanding decreases (see Text Box 10.3). This increased complexity at the higher (ecological) levels has serious implications for researchers as it means that issues like Cormorant-fisheries interactions, associated predator-prey relationships, and potential or actual ‘impacts’ of the birds on the fish are subject to decreasing scientific understanding.

10.4 Review of some key considerations for Cormorant-fisheries interactions

The spatial and temporal complexity of prey-predator systems, including those involving Cormorants and fishes (see also section 10.1), requires consideration of the ecological behaviour of both predators and

prey. Closely associated with this are the methodological considerations which form the bulk of this Field Manual. However, in order to interpret the resulting biological data, in an attempt to quantify the impacts of Cormorant predation on fish for instance, we need to consider ecological behaviour, particularly of the prey.

It is also important to acknowledge the close inter-relationships between Cormorants and their prey. For example, Cormorant behaviour is most likely to be influenced by the ‘availability’ of fish (see section 7.5 for a discussion on ‘availability’), which itself is heavily influenced by the behaviour of the fish themselves. At spatial and temporal levels, changes in fish availability are almost certainly the reason for Cormorants’ north-south winter migrations and also both their flock size whilst foraging at a particular site and their choice of that site, or ‘willingness’ to switch to an alternative one. Clearly, fish availability actually becomes zero in those waters that become ice-covered in winter and this must be one of the strongest drivers for Cormorants’ north-east to south-west seasonal movements (see chapter 6 of van Eerden *et al.* 2012). At the population level, the availability of fish, driven ultimately by seasonal changes in temperatures across northern Europe, will ultimately influence both timing and the number of both adult birds reaching breeding condition and of nestlings that fledge and leave the nest successfully (see chapter 7 of van Eerden *et al.* 2012). At the population level, Cormorant distribution in winter appears to be determined by temperature limits

and to the suitability of particular foraging habitats in relation to fish availability (see chapter 8 of van Eerden *et al.* 2012).

Ecological behaviour is influenced by a wide range of parameters. For instance, fish stocks are affected and regulated by abiotic and biotic parameters and so the data obtained by researchers from sampling must be considered as a ‘snap-shot’ of the population at a specific time (and place). Fish populations may be influenced by extreme events such as heavy flood or drought and these can be generally inferred from fish samples (for instance through sudden changes in mortality rate or loss). Unfortunately, the effects of many less extreme events are much more difficult to record in, or infer from, data from fish samples. Furthermore, the influences of such events on fish populations are likely to be related to the area over which they occur. Similarly, the area from which fish can be sampled (e.g. point, stretch, whole river, catchment), and hence over which the population can be ‘understood’, is likely to influence our level of understanding. Generally, the smaller the area sampled, the more accurate the population estimate but the less likely it will be to appreciate the influence of abiotic and/or biotic factors at the population level.

Interpreting Cormorant numbers is similarly complex. For instance, researchers may place different interpretations on day, night roost, and breeding counts. Furthermore, the ‘accuracy’ of the count is likely to fall as the area covered by the count increases. For example, counting the exact number of birds

using a day roost is likely to be considerably easier than counting birds foraging along a winding section of river. Thus researchers are constantly interpreting the data they collect within a given ‘frame’ that includes both the space and time-period under consideration as well as the specific research question for which the data were collected (this is not necessarily the same as the ultimate question one may want to ask of the available information — a question which might require different data).

10.5 The effect of Cormorant predation on fish — some words on data requirements

Where the fish removed by Cormorants are of an exploitable size and species, the losses will tend to have a direct effect on the numbers potentially available to a fishery. This will apply particularly where the fish have been stocked and are not expected to contribute to the natural production of the waters. The same will be true where there is no population compensation, either in stocks artificially maintained at levels above the carrying capacity or, for example, where the removal of Salmonid smolts by a predator will be expected to have a proportional effect on the numbers of returning adult fish. Where such losses occur, catches are likely to be reduced, since larger stocks would be expected, in general, to provide better catches.

These effects may be reduced, but are unlikely to be eliminated, if predation occurs at a stage where compensation occurs. However, as compensation effects tend to



Figure 10.5 Juvenile Atlantic Salmon *Salmo salar* and Three-spined Stickleback *Gasterosteus aculeatus* in a Cormorant's stomach contents. Photo courtesy of D N Cars.

apply over full generation cycles it may be very difficult to determine their extent. It should further be noted that if a stock is reduced by predation, catches may be significantly impacted even though this may not prevent the fish population from sustaining itself at the lower size.

As an example of an attempt to assess fish-eating bird impact on juvenile Atlantic Salmon *Salmo salar* from the sort of bird and fish data obtained by methods discussed in this Field Manual, Marquiss *et al.* (1998) compared consumption rates of birds (Goosander *Mergus merganser*, Red-breasted Merganser *M serrator*, and Great Cormorant *Phalacrocorax carbo*) with the best available scientific estimates of fish abundance (estimated as numbers of fish per 100 m² in relation to river width). These authors discussed a number of potential sources of error in their calculations. They are listed here to highlight difficulties in estimating impacts even in a relatively simple system.

- Bird density — data from the study river
- Bird diet — data from the study river

- Bird daily food intake — upper limit derived from literature
- Salmon standing crop — not measured directly. Based on data from four other rivers. Likely to be underestimated because of methodological limitations and does not take into account the seasonal movement of fish within the catchment

Marquiss *et al.* (1998) stated that at certain times and places, the fish consumption by the birds as estimated using these calculations suggested that the birds would remove all fish from the river within two months. That this did not happen implied that some of the study's assumptions were invalid. Either estimates of consumption were too high and/or the estimates of Salmon standing stock were too low. Alternatively, the figures and calculations could be realistic but the fish population might somehow be able to compensate for the recorded levels of predation (see Sections 10.7 and 10.8).

Clearly this research shows the difficulties in moving from estimates of fish consumption by predators to their impacts on prey populations. The inference from this and other studies seems to be that the fish losses to birds can be substantial, albeit impossible to quantify in population terms using commonly collected data.

Marquiss *et al.* (1998) also highlighted that a major problem in calculating the proportion of fish standing crop consumed by birds was collecting accurate data for all the necessary parameters at a specific site. The main priorities

These authors consider that attempts to quantify Cormorant impact at fisheries would benefit greatly from information relating to periods both before and after Cormorant presence. They also argue that better understanding between the variability within Cormorant and fish populations is needed, alongside recognition of the nature and scale of such variation. Requirements (many of which are described elsewhere in the Field Manual) are presented for both Cormorants and fish.

(A) Knowledge of Cormorant diet and biology

Diet

- Confidence in diet assessment methods appropriate to specific situation.
- Determination of prey species, size-range, prey selection, and associated temporal and spatial changes. Simply identifying prey fishes, either absolutely or relatively, is inadequate.
- Consumption rates for all prey species, not just those of commercial interest.
- Estimates of Daily Food Intake (DFI) — varying with season, energetic demands, calorific content of prey.
- Quantification of ‘impact’ requires that all the above are combined and may be compared to the situation without Cormorants.

Biology

- Cormorant demography — ratio of breeders to non breeders, sex and age ratio in relation to their associated diet and DFI.
- Seasonal foraging range — helps to understand local versus regional ‘impacts’ to fish populations.
- The timing, magnitude, and frequency of Cormorant foraging activities, in relation to the foraging site under consideration.
- Seasonal changes in these parameters.

Text Box 10.4 Requirements for quantifying Cormorant impact to fisheries (based on Wires *et al.* 2003: 391–2).

(B) Knowledge of fish populations and factors that affect them

Definition and scale – helping to develop criteria for what data are required

- A definition of ‘impact’ is essential — impact on populations does not necessarily equal impact on catches.
- The level of impact that triggers management action must be clearly defined and stated.
- One approach could be to define impact in economic terms [see 10.1] where losses can be attributed specifically to Cormorants — financial loss (impact) would not have occurred in the absence of Cormorants.
- Spatially, are impacts considered local (or site-specific) or regional? Such spatial differences will affect the likelihood of both an impact and our ability to quantify it.
- Cormorant impacts have to be considered in relation to other factors affecting fish populations and catches — studies of how other fish-eating predators (including fishes), angler/commercial harvest, pollution, and competition within the fish community affect fish populations will help understand the relative magnitude of a Cormorant effect.

Space and time

- Knowledge is required on the abundance of fishes and their distribution — including their ranges and movements — both spatially and temporally.
- Population indices for fishes are also required — ideally from regular species-specific fish surveys.
- The most useful data sets will be in the form of long-term trends.

Population dynamics and habitat characteristics

- Essential information includes information on dynamics of fish populations (not necessarily just those of commercial interest), including age-structure, mortality (including changes in the relative importance of different sources of it), survival, growth rates, and recruitment.
- Impact studies require a better understanding of compensatory effects on natural fish mortality.
- The most useful datasets will be in the form of long-term trends.

identified to allow more accurate calculations were to produce matched datasets (birds and fish) for specific foraging sites that provided:

- More accurate estimates of daily food intake of birds
- Knowledge about prey switching by birds and the role of alternative habitat
- Estimates of bird densities at foraging sites where there are dietary data
- Direct estimates of fish standing crop (abundance) at bird foraging sites and of fish movement patterns

In this context, an in-depth review of the types of high quality data (including those mentioned above) which are ideally required for scientifically quantifying Cormorant impact at fisheries is summarised in Text Box 10.4. Many of these issues are then discussed in more detail in later sections.

Whilst the information in Text Box 10.4 is fine as a research wish list, it is unrealistic as a set of recommendations for what might be accomplished in practice. There is thus a need to recognise the need for a pragmatic approach to quantifying Cormorant predation at fisheries (see also sections 10.1, 10.2 and 10.13). Indeed the fisheries themselves are often managed very successfully on far less information than that listed here.

It is clear that obtaining relevant data that allow us to quantify populations of either Cormorants or of fish species is difficult and many of these problems are associated



Figure 10.6 How many Cormorants? Do large numbers of fish support large numbers of birds? Are fish affected in relation to Cormorant numbers?

Photo courtesy of Janis Kuze.

with the methodological difficulties discussed elsewhere in the Field Manual. These problems are often further compounded by the common mismatch (in time and/or space) between the available Cormorant and fish data. Generally, assessment becomes increasingly difficult as one moves from small highly managed water bodies to larger more natural ones (see also sections 7.5, 7.6 and chapter 8). Moreover, there is a general consensus that the relevant bird data are more readily available, and perhaps more robust, than many of the available datasets on fish, their population dynamics and status and distribution. Ideally, fish data should include some knowledge of the community structure and productivity of indigenous stocks and the effects of possible compensatory mechanisms, and also of the effects of any stocked fish.

Finally, far from being a simple predator-prey relationship, those between Cormorants and fish

are ecologically very complex. The next section discusses this complexity, particularly in relation to the careful and accurate interpretation of data.

10.6 Predator-prey relationships — some concepts

This brief review of some of the key ideas and concepts associated with predator-prey relationships is drawn from general texts (e.g. Cherrett 1989, Crawley 1992, Begon *et al.* 1996) as well as specific works on fishes (Pitcher 1986, Wootton 1990). It follows very closely the main points discussed by Marquiss *et al.* (1998, pp 62-64).

In practice, a number of density dependent and density independent processes can act on a population at any one time (see section 10.7). Their relative importance usually varies in space and time, thus altering the position of the

equilibrium density within and between populations. Furthermore, these processes are likely to affect populations differently depending on when in the life-cycle they occur. To assess any effects of predation on prey populations, it is vital to know how predators respond to changes in the density of their prey. There are essentially two types of response. First, a numerical response whereby higher numbers of prey are likely to support higher numbers of predators. Second, a functional response whereby the number of prey eaten by each predator is affected by variation in the density of that prey.

Such functional responses are likely to be affected by a number of factors. For example, not all prey are equally vulnerable to predation. Predators may select old, young, or sick prey that are easier to catch. Where this is the case, predation is less likely to affect the overall population dynamics of the prey. Conversely, predators may select highly conspicuous prey that are feeding actively or breeding and which (if not eaten) would have made a large reproductive contribution to the population. Similarly, not all individual prey will have equal access to refuges from predator attack — and in many cases those with the best access to cover might be the ‘fittest’ individuals. Thus, in some cases, those prey making the biggest reproductive contribution could be least vulnerable to predation. Conversely, if a prey species relies on being cryptic to avoid predation, prominent territory holders may be most vulnerable.

Considering predator-prey interactions within the functional response framework allows

researchers to predict that several factors besides the densities of predators and prey are important. ‘Specialist’ predators consume a single, or small number of, prey types (or species) whilst ‘generalist’ predators feed on a wide variety of prey. In theory, the effects of specialist and generalist predators on their prey are likely to be very different. Generalists are likely to have a bigger impact on their ‘preferred’ prey through their ability to switch to other prey types (species). Studies of predation should not therefore merely consider the ‘preferred’ prey in isolation but also consider other accessible prey and the proximity of alternative foraging sites. In the case of Cormorants (a generalist predator), this is likely to mean that most, if not all, of the fish assemblage(s) in habitats used by the birds for foraging might be considered and quantified to some degree. In some situations this is actually less of a problem in practice because Cormorants

are foraging in modified habitats and/or sites where only one (or a few) fish species occur or are being raised (e.g. fish farms). Thus understanding fish stocks, in relation to their associated habitats or fishery types is important.

10.7 Using fish stock assessments as a basis for assessing Cormorant impact

Commonly, the results obtained from fish stock assessment techniques (see chapter 8) do not provide an estimate of absolute abundance of the fish stocks present in a water body, but they may give an ‘index’ of stock abundance. This can nevertheless still be used to identify trends in fish abundance and alert fisheries’ managers to changes and potential problems. There are a number of inherent difficulties associated with sampling freshwater fish stocks that need to be borne in mind in relation to the integration of fish stock assessment data and



Figure 10.7 Fish catches from a Greek coastal fishery — a very large ‘open’ system. Photo courtesy of D N Carss.

parallel Cormorant data when attempting to quantify the impact of the birds at a specific fishery.

Information on the distribution of fish species and the size of fish populations is only one of the requirements for trying to understand the interaction between Cormorants and fisheries. This is because predator-prey ecology involves the complex interaction between two dynamic systems, and the various factors affecting them. While predation at an individual level (e.g. a fish consumed by a Cormorant) requires simply that a foraging predator and a suitable prey are at the same place at the same time, this does not explain the possible implications at the long-term, population level, nor does it provide any measure of whether 'serious damage' has resulted (from a biological perspective, but there are others, see Text Box 10.2 and sections 10.1, 10.2 and 10.13).

In relatively simple, man-made structures like fish ponds or fish farms (i.e. spatially 'closed' systems), where controlled conditions apply, estimating the mortality of a fish stock due to predators, and hence the level of impact, can be relatively straightforward. For example, yearly losses in the absence of Cormorants could provide a basis for comparison with sites visited by the birds. Although other explanations for the losses (see section 10.12) would need to be ruled out before a Cormorant effect could be established unequivocally.

Inevitably, understanding predator-prey interactions and assessing the status of fish populations in more natural systems like running waters,

lakes and the marine environment (i.e. spatially 'open' systems often with reduced management and/or fish stocking) is much more complex. Detailed long-term monitoring of such sites, in the absence of pressures such as Cormorants, may allow the natural variability in fish populations (standing crop, recruitment, size structure of the population, cohort mortality) to be described and to serve as a basis for comparison (e.g. in terms of fish density, length-frequency distribution, etc.) with similar water bodies affected by Cormorants. Information on the number of Cormorants present (e.g. Cormorant-days in a certain period or area, see section 3.4.1) and their diet and daily food intake (see chapter 4) will also be important in such studies. However, the costs and practicalities of such monitoring mean that such rigorous data sets on both birds and fishes will inevitably be confined to relatively few sites.

There are certainly some cases where such data on fish and Cormorants are available that allow us to consider the estimated numbers of fish eaten by the birds in relation to some measure of the standing stock of the prey. Nevertheless, they do not necessarily allow us to assess the impacts of predation on fish populations because the predator-prey interactions are complicated (Russell *et al.* 1996, see also sections 10.10 and 10.11). Natural variation in fish populations and the effect of this on both fish production and catches makes it additionally difficult to determine the effect of a single factor, such as predation, on the numbers of fish present. The following sections provide some background information on the



Figure 10.8 Stocking waters with fish is a common practice in many freshwater fisheries but it can often have large effects on the ecology of the system. Photo courtesy of INTERCAFE.

population regulation mechanisms affecting freshwater fish stocks and their possible effects on production and catches.

10.8 Natural regulation in fish populations

The species composition of fisheries, and the size of fish stocks within them, can vary enormously, under the influence of a wide range of factors. For many species, the population size is determined as a balance between gains (births, immigration) and losses (death, emigration). If the rates of either gains or losses (as a proportion of the population) are unrelated to population density, processes are said to be 'density independent'. If, as population density increases, the proportional rate of gain decreases (or of loss increases), then processes are considered to be 'density dependent'. Generally, in natural fisheries, stock levels are regulated by various factors and they serve to provide an upper limit or 'carrying capacity' for

the fish stock which involves both density independent and dependent factors. In effect, carrying capacity represents the stock size that, on average, the habitat is able to support. Where gains equal losses, the population is at equilibrium but if there is a switch (in either direction) only density dependent processes can act to re-establish equilibrium in a process known as 'regulation'. However, in managed or intensive fisheries, stock densities that significantly exceed the natural carrying capacity can be achieved through additional stocking and other management practices. This is typically confined to smaller, spatially closed sites.

In healthy natural populations, the number of fish produced will generally exceed the numbers which can be sustained by the available resources. As a result, natural mortality will tend to result in the population declining towards the carrying capacity level. Under these circumstances, some or all of the fish lost to predation may simply be replaced, in the long term at least, by fish that would otherwise have died from other causes, a process known as 'compensatory mortality'. This mechanism depends on there being continual competition for available resources, such as space or food. It therefore tends to have stronger effects on the relatively large numbers of very young fish in a population and less on the smaller numbers of large adults. It should be noted that the potential for compensatory mortality is greatly reduced in stocks below carrying capacity (the situation for the majority of Salmon stocks in different parts of Europe for example). Compensatory effects can also be affected where the

environment ceases to impose a limit on the carrying capacity. For example, in Atlantic Salmon *Salmo salar* and Sea Trout (migratory Brown Trout *S. Trutta*) there is thought to be virtually no compensation after the fish reach the smolt stage and emigrate to sea. Furthermore, for all fish stocks maintained at high levels (i.e. above carrying capacity) through stocking, there will be no natural compensation for fish losses to predation.

The compensatory processes also mean that natural mortality will be reduced when stocks fall below their carrying capacity due to reduced competition for resources. As a result, the productivity of the population (e.g. fish growth and number of surviving offspring per adult) will increase as the stock size falls. This means that if stocks are depleted by increased levels of predation (or human exploitation), they may still be self-sustaining, albeit at a reduced average level. Thus fish populations may be self-sustaining at a wide range of population sizes below their maximum carrying capacity. Only if the rate of removals (by whatever cause[s]) exceeds the maximum productive capacity of the stock will the population collapse. A clear implication of this is that where populations are reduced, even if they are self-sustaining, catches will tend to be depressed and impacts may still be occurring, albeit difficult to quantify.

10.9 The effect of natural variation on production and catches

The scope for compensation to operate within a fish population

will be influenced by the timing and duration of any impact from predators, other biotic and abiotic limiting factors and by year-to-year changes in the productivity of the stock. Moreover, compensation also only works within certain limits. For example, many fish populations are subject to substantial variation as a result of fluctuations in the year-class strength of different fish species, with ambient water temperatures in the first year of life being a key determining factor. The sustainability of such fish stocks often depends upon occasional large year-classes, which remain identifiable as the fish grow over a period of years. In addition, in larger rivers and lakes, fish populations will typically be larger in overall terms but occur at lower densities and be more spatially separated than those in smaller habitats, and this may confer greater resilience against predation over the longer term.

There are, of course, many other factors (such as human exploitation, disease, other bird and mammal predators, and piscivorous fish) that also impact on fish population size and structure. However, the assumption that catches of fish will be larger where there are larger stocks of fish in a water body (i.e. that catches and stocks are positively related) is widely accepted by anglers and fishery managers and supported by a substantial body of scientific evidence. Consequently, fisheries managers commonly resort to stocking to increase fish densities. However, the introduction of stocked fish may make the quantification of Cormorant impact even more complex because the population dynamics of the

prey — perhaps in this case, stocked fish — are not constrained by natural gains and losses (see below). Moreover, fish introduced through stocking may be more vulnerable to predation than those occurring naturally, particularly during the first days of release. Cormorant predator-prey relationships are clearly complex and so can be very difficult to understand in terms of biological impact, an issue discussed in the following section.

10.10 Why do biologists find it difficult to measure a Cormorant 'impact' at fisheries?

As discussed earlier (section 9.1), the word 'fishery' has different meanings to different people, similarly there are many different 'frames' through which Cormorant impact at fisheries may be interpreted. The biological perspective is only one of several, often inter-woven, perspectives that can be applied to the issue of Cormorant impact on fisheries (see also sections 10.1, 10.2 and 10.13 and chapter 12 of Marzano & Carss 2012). **INTERCAFE** thus recognises (see also Marzano & Carss 2012) the management needs of many involved in commercial and recreational fisheries where the evidence base has to weighed against many factors other than natural science, including social, cultural, economics, and legislative ones. Nevertheless, biologists have long been charged with addressing and quantifying impacts (see reviews in Marquiss & Carss 1994, Russell *et al.* 1996, and also Carss *et al.* 2009). This has invariably led to frustration amongst fisheries



Figure 10.9 Cormorants can sometimes compete directly with fishermen for the same species and sizes of fish. Photograph taken from Fishing Club Bohinj presentation to INTERCAFE.

concerns, as scientists have very seldom been able to collect irrefutable evidence of Cormorant impact, particularly at larger fishery sites. This section, deliberately focussing on the biological (natural science) perspective, further explores why this might be so.

Usually, 'Cormorant impact' is taken to mean a situation where birds are eating sufficient fish in a system so as to affect it negatively from a human perspective. In practice, this almost always means a reduction to fish catches, fish value, or to a specific portion of that catch (e.g. a particular species or age/length class of individuals). The relationship between a fish stock size and the catch can be affected by a range of factors. Typically, though not always, larger stocks will result in better catches (this is, after all, why fish are stocked at some sites) and there are published accounts for many fish species indicating a

positive relationship between catch and stock size.

There may also be a difference between the catches made by humans and by other predators such as Cormorants or predatory fish, and this is more likely in 'well-balanced' aquatic ecosystems or those under more natural conditions, where the level of competition for the same individuals of the same species and sizes can sometimes - though certainly not always - be relatively small between humans and Cormorants. There is, however, even greater potential for direct competition in some highly managed fisheries, for example at intensive fish farms, or angling lakes stocked regularly where fish community structures may be quite simple or even monocultures.

Besides direct losses, there is also a range of 'indirect' Cormorant

impacts that may need to be taken into account. These include:

- the physical damage from the birds to those fish that they are unable to swallow or which escape having being captured;
- the risks of birds spreading diseases and/or parasites between fish stocks;
- the predation on smaller individual fish which, had they not been eaten and survived to grow larger, would have been legitimate catches for commercial fishermen, quarry for recreational anglers, or part of the harvest at fish farms;
- predation on smaller fish species of no commercial value that are prey for larger fishes that are themselves the target for human fisheries; and
- the ‘stress’ caused by foraging birds to fish, which causes them to move into different habitats, change their feeding habits, lose condition, become more susceptible to diseases or parasites, grow more slowly, and generally be less ‘available’ (and valuable) to human fisheries.

In most cases other than in relation to physical damage to fish (see chapter 9) and parasite infections (Cormorants and other fish-eating birds are known to be the definitive hosts for a number of parasites which also affect fish), definitive biological data may be difficult to collect. Clearly further research is necessary to further understand and quantify these issues.

Leaving the indirect biologically-based impacts aside, the remainder of this section focuses on the scientific requirements for a quantification of the direct impacts

of Cormorants on fisheries. In relation to the ecological processes crucial to predator-prey interactions, ecologists considering natural enemies and their prey need to address several interrelated questions (Crawley 1992):

- How do predators affect the abundance of their prey?
- Can predators regulate prey population density?
- What determines the abundance of predators?
- What factors influence the pattern of dynamics exhibited by a particular predator-prey relationship?

These appear to be simple questions — if a predator kills prey, the prey must become less abundant and, if prey numbers decline, predators must switch to another prey, or foraging site and/or become less abundant themselves. However, the consensus amongst researchers is that these are far from trivial questions and the

inferences just mentioned are too simplistic to be realistic in nature.

It is beyond the scope of the Field Manual to go into each of these questions in detail but, nevertheless, it is clear that a huge amount of scientific data would certainly be required to answer each of these questions categorically for any specific Cormorant predator-prey situation. Focussing on the fourth question above, in relation to Cormorants and fisheries for example, researchers need to consider a number of important issues. Moreover, they can not address these questions simultaneously, by experiment or in theory, as these relationships turn out to be extremely complex and require, in theory at least, a large amount of necessary information (see Text Box 10.5).

In reality, the requirements detailed in Text Box 10.5 are essentially a wish list and is wholly unrealistic in the context of most Cormorant-



Figure 10.10 Sub-Alpine river in Slovenia — when lowland standing waters have ice-cover in winter, such running waters can be ‘hotspots’ for Cormorants. Photograph — Shutterstock.

1. The intrinsic rate of increase of the prey — the rate at which the prey fish population increases in size — the change in fish population size per individual fish per unit time.
 2. The functional response of the predator — the relationship between the Cormorant's consumption rate of fish and the density of those fish.
 3. The predator's spatial foraging behaviour — the foraging behaviour of Cormorants in relation to the space they are currently using as a foraging range.
 4. The nature of prey density dependence — the way in which the death rate in the fish population increases, or the birth or growth rate of it, decreases as the density of the fish population increases. Alternatively, — the way in which the death rate in the fish population decreases, or the birth or growth rate of it, increases as the density of the fish population decreases.
 5. The nature of predator density dependence — the way in which the death rate in the Cormorant population increases, or the birth or growth rate of it, decreases as the density of the Cormorant population increases. Alternatively, — the way in which the death rate in the Cormorant population decreases, or the birth or growth rate of it, increases as the density of the Cormorant population decreases.
 6. The relative slopes of the isoclines at the intersection — isoclines are lines drawn on a two-dimensional plot of predator density against prey density. They link points that give rise to the same rates of population increase for the species being considered. Thus they divide the area of the graph into a zone of prey increase and a zone of prey decrease. Similarly, the predator isocline divides the graph into an area of predator increase and one of predator decrease. Isoclines intersect where the rate of growth of both predator and prey is zero. In this manner it is possible to relate changes (increases or decreases — defined by the slope of the isocline) in the Cormorant to those in the fish and *vice versa*. It suggests strongly at what densities Cormorants might be limited by the fish (or by other things) and when the fish might be limited by Cormorants (or by other things).
 7. The size of the prey refuge — this can vary considerably and encompasses every situation where fish are 'free' of Cormorant predation. Prey refuges could thus include a hiding place for an individual fish, the avoidance behaviour or crypsis of fish, habitats that are inaccessible to Cormorants, habitats that do not overlap with the geographical range of Cormorants, the 'choice' of the predator to select an alternate prey, and the presence of fish in an area of low Cormorant density.
 8. The rate of predator immigration — the movements of Cormorants into the population from elsewhere.
 9. The rate of between-patch prey dispersal — fish are not uniformly distributed across habitats or within them but tend to be concentrated in 'patches' (e.g. shoals of fish in a lake, higher densities of fish in particular stretches of river — or at particular times of year). The dispersal rate of interest here is that at which individual fish spread away from each other between these patches.
- It is important to note that the above refers to the simplest case, that of a 'specialist' predator — one taking a single (or few) prey type(s). As 'generalist' predators, Cormorants consume many different types of prey fishes and so trying to explain the dynamics of this more complex predator-prey interaction could 'exhibit chaotic dynamics of almost unimaginable intricacy' (Crawley 1992, p89).

Text Box 10.5 The minimum amount of necessary information to understand the dynamics of one specialist predator and its prey (based on Crawley 1992, p89). Clearly, this list is too simplistic for Cormorants foraging anywhere but in a single-species monoculture fish pond (see text).

fishery conflicts. Moreover, the list is too simplistic for all but the simplest predator-prey relationship where Cormorants may be foraging solely on a monoculture of fish. This highlights a major problem facing researchers — that even complete understanding the dynamics of the simplest predator-prey relationship is likely to be unrealistic — and leads to a recognition that researchers will never be able to provide all the answers. This again highlights that the need for a pragmatic approach is needed both in assessing Cormorant impact at fisheries and in managing Cormorant-fisheries conflicts (see section 10.13).

Scale is also a vitally important consideration in predator-prey relationships. For example at the smallest spatial scale, every death caused by a predator could be considered as a local extinction (Crawley 1992). At a large spatial scale, the interaction might be stable - there may be little overall effect of predation because of local instabilities or as a result of local regulating mechanisms. Similarly, temporal scale is also important as there may well be potential for short-term impacts (on fish catches or income, say) but perhaps compensation and/or recovery (at the population level) in the fishery over longer time scales.

For species that live in fragmented landscapes as ‘sub-populations’ separated in space, local extinctions of prey may occur following the discovery of a patch by predators. In theory, this may be the case at some predation ‘hotspots’ (e.g. Carp *Cyprinus carpio* aquaculture ponds, stretches of sub-Alpine rivers) where Cormorants may consume a

large proportion of the fish available in a relatively small local area relatively quickly after ‘discovering’ the site. It seems that such localised predation ‘hotspots’, where fish appear particularly vulnerable to predation and where losses to them may be considerable, are the main focus of the greatest concerns of fisheries managers, fishermen and anglers. However, although this is a widely held view of the sequence of events, the ‘hard’ scientific evidence may not be particularly robust for the reasons already cited.

In conclusion, each of the components of a specific predator-prey relationship is based on a simplified or abstracted description of the real world. Intuitively, people may think they know the answers to some (if not all of them) and, in some cases, there are scientific data to help understand at least some of these components. However, when researchers attempt to put them together in order to understand the dynamics of a specific predator-prey relationship in nature, immensely complex systems are formed. Given this biological complexity and the recognition that scientific evidence for the numerous permutations of Cormorant-fisheries interactions is likely to be always incomplete, where can researchers and other stakeholders turn to better understand the potential impact of the birds on fish from a scientific perspective?

10.11 Manipulative field experiments and understanding complex ecological processes

Kitchell and Carpenter (1993) explored how best to understand

complex ecological processes for so-called ‘trophic cascades’ in lakes. Their work focused on predator-prey relationships in these habitats but had fish as their top predators. Here, variability at the top of the food web (acting through the selective predation by the fish community) was hypothesised to ‘cascade’ through the zooplankton and phytoplankton to influence ecosystem processes (e.g. primary production). These researchers set out to understand this process, beginning with an exploration of how best to test their ideas in the field. Thus, although this work will not help us directly with our question of whether Cormorants impact upon their fish prey (it does not include fish-eating birds as top predators), it may suggest how best to look for, and measure in biological terms, Cormorant impacts in real world situations.

Kitchell and Carpenter (1993) considered five essentially different ways in which researchers can test their ideas about ecosystem processes. These are comparative studies, long-term studies, simulation analyses (modelling), mesocosms (laboratory or field enclosure experiments), and experimentation at the ecosystem scale. Whilst each has its benefits and associated limitations, they considered experimentation at the ecosystem scale to be most appropriate, complementing this where appropriate with other methods. There is a large body of literature on the problems and pitfalls of experimental design in ecology (see for example Krebs 1989, Raffaelli and Hawkins 1999) and whilst it is not within the scope of this Field Manual to discuss all these, some consideration of field

Given the time required and the geographic area to be covered, it is perhaps not surprising that relatively few experiments have attempted to assess the effect of fish-eating birds on fish stocks at a catchment scale. Moreover, those experiments that have been conducted have involved sawbill (*Mergus* spp.) ducks not Cormorants. Experiments have also focussed on reducing bird numbers, thus reducing their predation pressure on the fish, and have mostly been conducted in Canada in an attempt to increase salmon harvest. These experiments have been extensively reviewed (Marquiss & Carss 1994, Russell *et al.* 1996, Marquiss *et al.* 1998) and none of them unequivocally showed that killing sawbill ducks (reducing the numbers of predators) increased fish (salmon) harvest, mainly because of poor experimental design or implementation.

Text Box 10.6 Experiments to reduce the impact of fish-eating birds on fish stocks.

experimentation is necessary here.

Scientifically, an ‘experiment’ is a carefully-designed process undertaken by researchers to test a specific hypothesis about nature — for example, a ‘treatment’ is applied to one area (or ‘experimental unit’) and not to another. Any differences between the treatment and the so-called ‘control’ area can then be compared. For the results of an experiment to be convincing, there must be clear-cut differences between the treatment and the control. These differences will



Figure 10.11 Do fish populations (stocks, or catches) change as a result of Cormorant presence? Photographs—Shutterstock.

be more convincing and could be statistically significant if they are shown consistently in more than one treatment area compared with more than one control area (each of these pairs being a so-called ‘replicate’). This replication is important because otherwise it could be argued that the differences are nothing to do with the experimental treatment but are due to other factors. Thus, if done correctly, statistical analysis can then resolve a particular cause and its specific effect(s).

However, as noted above (section 10.10), real-life Cormorant-fishery interactions are generally so complex, and scales so large, that standard scientific experimentation is not possible. Thus, in the case

of fish-eating birds and fisheries, such manipulative experiments have usually involved the large-scale removal of the predators (or a significant reduction in their numbers) with the aim of measuring a subsequent ‘improvement’ in some measure of the fishery. However, the lack of replication often invalidates such ecological field experiments (see Text Box 10.6) and so it is not possible to relate any measured effect (if, indeed, there is one) to the specific act of reducing bird numbers.

It therefore seems that unequivocal scientific evidence of Cormorant (or other fish-eating bird) impact on fisheries is extremely difficult to obtain. This is true whether impact assessments are direct comparisons



of bird and fish data or whether they are indirect, through the real world experimental manipulation of predator numbers. However, this lack of evidence does not mean that birds like Cormorants do not have an impact on fish stocks — it merely emphasises that it is very difficult to demonstrate this scientifically.

10.12 How best to make progress? Data requirements and methodology

For the researcher, perhaps the most relevant development in the consideration of Cormorant-fisheries relationships is the application of statistical techniques, novel to ecosystem ecology, that are appropriate for real world experiments (Carpenter 1993). Like the Cormorant-fisheries situation,

These factors need to be considered carefully as possible explanations, before claims that a reduction in fish abundance has been caused solely by Cormorant predation.

- Past events and effects: sudden severe impacts such as toxic agents, waste water, extreme flooding.
- Climate: long-term effects.
- Chemistry: water parameters such as ammonia, nitrite, nutrient levels, pH, 'hardness'.
- Water-physics: water parameters like temperature, oxygen, conductivity.
- Hydrology: amount of discharge, flow regimes and water levels.
- Morphology: river bed, river bank characteristics, provision of cover.
- Food: abundance and availability of food.
- Diseases: parasites, bacteria, viruses.
- Growth: leading to an increase in biomass.
- Fisheries management: human interference to wild fish stock, including exploitation and stocking, also the presence of alien species.
- Predation by other species of fish-eating birds, mammals (e.g. American Mink *Mustela vison*, Otter *Lutra lutra*, or seals *Phoca* spp.), and/or predatory fishes such as Pike *Esox lucius*, Perch *Perca fluviatilis* and Pikeperch *Sander leucoperca* in freshwater and Mackerel *Scomber scombrus*, Cod *Gadus morhua* and Bass *Dicentrarchus labrax* in marine ecosystems.
- Density dependent mortality and natural population variability: mortality changes due to changing fish densities inducing fluctuations in measured fish density/biomass between years.

Text Box 10.7 A checklist of key factors that could significantly influence fish abundance.

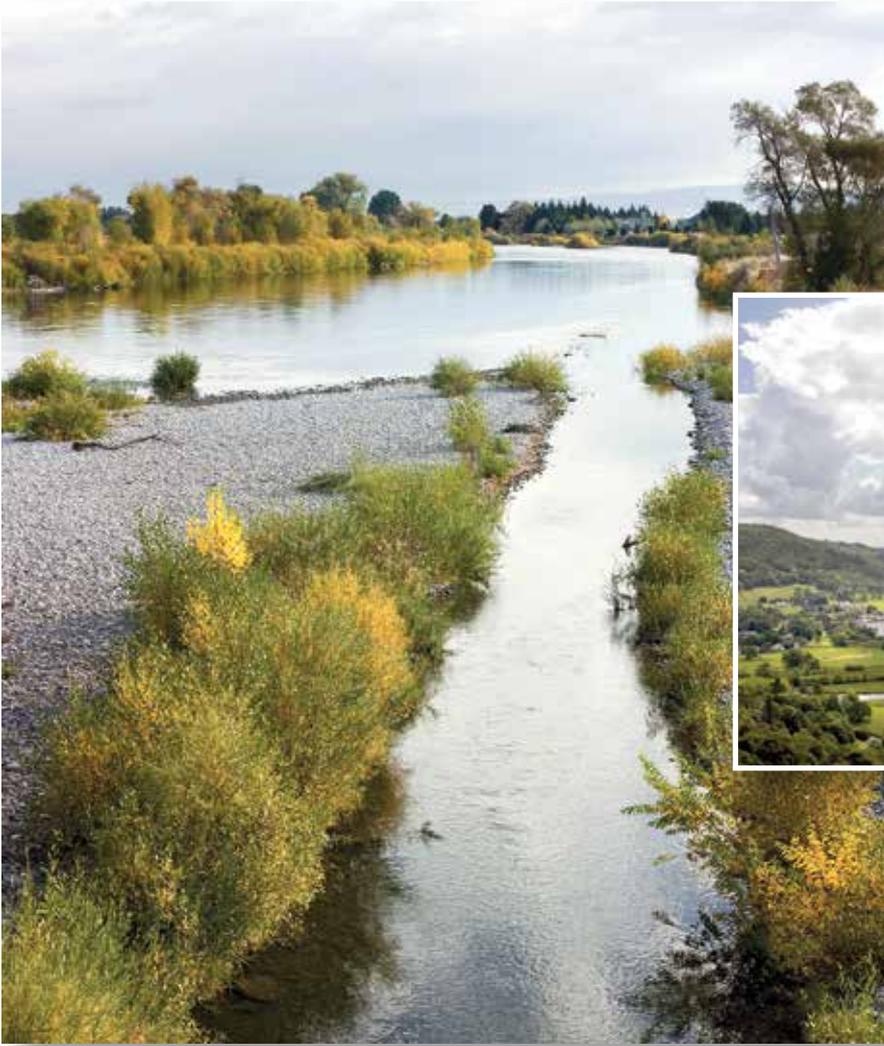


Figure 10.12 Geographic scale is a key ‘frame’ through which to view the likelihood of Cormorant predation (and of quantifying it) at a fishery; small stream flowing into a river main stem; large lake. Photographs—Shutterstock.



Carpenter (1993) argues that interpreting what happens in his study lakes during experimentation can be reduced to two simple questions: Did the system change? If so, did the manipulation cause the change? Analogous questions in the context of Cormorant-fisheries studies would be:

- Did fish populations (stocks or catches) change?
- If so, did the presence of Cormorants cause the change?

Carpenter (1993) states that, without replication, it is only possible to answer the first question through experimentation. An alternative experimental approach

to the replicated manipulation discussed above is to make before-after comparisons, where the experimental unit can act as its own control. Fisheries and wildlife management often rely on time-series data in which a management manipulation occurs at a given time. However, the problem here is that without an adequate control, all before-after comparisons assume that natural systems stay essentially the same over time and as Krebs (1989: 270–71) points out this is ‘a dubious balance-of-nature model that has been found invalid time and time again in ecological work. Populations and communities change over time in a way we only dimly understand, and to achieve

reliable statistical inference we need spatial controls for all ecological experiments.’ Nevertheless, careful data collection and interpretation, and a good understanding of the dynamics of the fishery under investigation in terms of natural regulation (see section 10.8) and the likely effects (and scale) of other factors (besides predation) on the fish population (see Figure 10.1, also text below), the ‘before’ situation might be able to act as a legitimate control.

To answer the second question above, one must show that the manipulation (or the presence of Cormorants) was the most plausible reason for the change. This can either involve looking very carefully at the before-after situation in the same system (see above) or looking at similar systems (with and without Cormorants), well-argued ecological interpretation and an acceptable level of significance



Figure 10.13 Double-crested Cormorant *Phalacrocorax auritus*.
Photograph — Shutterstock.

between any recorded changes in fish in waters with and without Cormorants. Careful use of time series statistical techniques (looking for non-random changes in the system under study, see Carpenter 1993) could thus help us search for and quantify a Cormorant ‘impact’ at a fishery. It is also important to remember that losses to predators such as Cormorants (which can be estimated with reasonable accuracy, see chapter 3) should be viewed in the context of the other environmental and anthropogenic factors which might affect fish stock (and ultimately catch) size (Russell *et al.* 1996, and also see Text Box 10.7).

One further important issue to consider here is the amount of data available to researchers. Clearly the longer the run of data both before and after Cormorants, the more likely it will be to detect any differences between the two situations and begin to explore whether it is most likely to have been caused by the birds. A small number of data points either before

and/or after Cormorants will make it difficult to detect any effect amongst the natural variation in the data. The worse case scenario (and one commonly facing researchers) is thus that there are few (or only single) data points either before and/or after Cormorants. In such situations, it is very difficult to

assign any effect specifically to Cormorant predation as there are a number of factors that could also be affecting the fish population of interest (see Text Box 10.7). Each one could have a significant, measurable, effect on the results of fish sampling, potentially as big (or bigger) than the likely effect of predators such as Cormorants.

Typically, the same general suite of factors can affect a variety of water bodies and wetland habitats frequented by Cormorants and where fish samples may be collected. These include ponds, rivers, lakes, and coastal areas and it is not uncommon for researchers to obtain fish data from any of these habitats in the form of biomass records for fish species. Regardless of the form of the data (i.e. long-term time trends or before-after comparisons), the key issue is often one of interpretation — is Cormorant predation the most likely cause of any observed



Figure 10.14 Typical shallow lake Alewife *Alosa pseudoharengus* spawning habitat in Connecticut, USA. Photograph — Shutterstock.

changes in fish biomass, numbers or some index of these?

However, whilst this holistic approach (Text Box 10.7) is useful to assess the various factors likely to have influenced fish abundance from a purely biological perspective, it is probably unrealistic to think of being able to eliminate some of them (e.g. climate effects) as likely causes of change. Similarly, for many Cormorant-fisheries conflict situations, assessing these factors will be beyond the scope of many stakeholders, including researchers. There is another danger in this approach in that it could be seen as requiring an unreasonable burden of proof that Cormorants are the sole cause of fish declines. However, on the other hand, an awareness of it may guard against the intuitive reaction that if fish abundance has declined then Cormorants must be solely to blame. Commonly such assessments are more likely to boil down to a number of factors and hard practical choices. If fish are in decline and management is needed, how do fisheries owners and managers prioritise addressing the various limiting factors, taking into account such things as the likely scale of any effect, practicalities, costs, and short- versus long-term considerations?

This chapter has discussed the general picture of a theoretical Cormorant-fish 'system', showing that both the complexity and the ecological knowledge required to understand it, increases with the size of the system. It also discusses how the accuracy of available scientific sampling methods decreases with the increasing size of the study system or water body. Similarly, with this increase in

scale, interpretation of the results becomes more complex. Smaller waters and their associated fish communities often react faster to environmental factors while larger ones may be buffered to some extent. Similarly, Cormorant predation is more likely to have an impact on a fishery or particular fish species in a smaller water body than in a larger one.

The increasing complexity of sampling Cormorants and fish rigorously in larger water systems, the need for more intensive research effort, accompanied by a general reduction in the accuracy of the results, could lead to questioning whether scientific understanding of real-life Cormorant-fisheries interactions is possible at all. Such a question should not be seen as a means of deflecting the issue of predation into ever more complex ecological processes, but a recognition that measuring predation, in a scientific context, is also extremely difficult. Nevertheless, there are numerous claims of Cormorant impact at fisheries and factors besides 'scientific proof' could quite legitimately be used to define such impact (see also sections 10.1, 10.2 and 10.13). Ideally, with current political demands for evidence-based policies, researchers should try to quantify the effect(s) of Cormorants on fisheries of interest to humans, but this will inevitably be constrained by practicalities and there will be a need for a level of pragmatism in assessing Cormorant-fishery conflicts.

As this Field Manual demonstrates, there are robust methods with which researchers could address many issues and make their



Figure 10.15 Double-crested Cormorant after a successful foraging bout. Photograph—Shutterstock.

results comparable with other investigations through the standardisation of methods. Furthermore, there are strong pointers as to how best develop study designs that will give maximum insight into the biological reality of the system, through the collection of rigorous field data. In addition, a broader understanding of the diverse factors affecting both Cormorants and fish can only help researchers tease apart any Cormorant impact on fisheries, but will also be of value for day-to-day management practices.

Whilst most available estimates of the impact of bird predation on fish catches have relied on either experiments or theoretical modelling, the findings discussed here suggest that when used in isolation, neither approach is likely



to prove entirely satisfactory (see also Marquiss *et al.* 1998: 80). Clearly, large-scale catchment experiments are likely to be cost-prohibitive and of limited application beyond the time and place in which they were conducted. The alternative, of modelling Cormorant predation, is theoretical and too dependent on untested assumptions to provide a reliable tool for fisheries management (for example see Marquiss *et al.* 1998: 53). Thus an iterative ‘model-field experiment-remodel’ approach may be the most efficient way forward, where the validity of model predictions are tested in the field through observation and (preferably) experiment. Results can then be used to refine the original models, which can be tested again.

This approach would lead to increasing levels of understanding, and a higher likelihood of researchers understanding the

effect of Cormorant predation, amongst other factors, on fish. Indeed such an approach has been adopted by researchers in the USA investigating the impact of Double-crested Cormorant (*P. auritus*) predation on fish including the Alewife (*Alosa pseudoharengus*) in a shallow lake and associated water bodies. Counts of Cormorants and assessments of their diet were combined with a bioenergetics model of their food consumption and with estimates of fish numbers and mortality. In this case, the authors concluded that although the Cormorants were important predators of spawning Alewives (consuming 30% of the spawning stock in 2005 and 18% in 2006 and representing 48% of the overall mortality of spawning fish in 2005), they did not have notable impact on fish mortality or population size, concluding that under current circumstances, they did not pose an immediate threat to the recovery of regional fish stocks (Dalton *et al.* 2009). The authors recognised, however, that Alewives would not be able to produce sustainable year classes below a critical spawner density and that Cormorants had the potential to cause such impacts in years of low Alewife escapement with detrimental consequences for regional alewife populations.

10.13 Concluding remarks — integrating perspectives

As described and discussed in detail in INTERCAFE’s publication ‘Cormorants and the European environment: exploring Cormorant status and distribution on a continental scale’ (van Eerden *et al.* 2012), Cormorant

numbers and distribution mirror both the environmental status of aquatic environments and their condition. The decisive factors for Cormorants on a site-by-site basis are ultimately the availability of, and accessibility to, water and food resources, while climate and prevailing weather conditions are the most relevant driving forces for large-scale movements, distribution and length of stay. It is within this dynamic framework that attempts to measure Cormorant impact at specific fisheries are made.

Importantly, it is also clear that in many places Cormorant predation (and any resulting impact) on fisheries is occurring against a backdrop of increasingly rapid environmental (and social, cultural and economic) changes (not always negative) across many European wetlands. Although many who make a living or spend their recreational time growing and/or catching fish share concerns over these wide social, economic and environmental issues, they may feel powerless to influence them and so it is sometimes easier for them to blame Cormorants for reduced fish catches or changes to fish community structure (Carss *et al.* 2009) even when this is not necessarily proven.

Given this situation, and the ecological complexities involved (see section 10.3 and Text Box 10.4 and also van Eerden *et al.* 2012), the impact of Cormorants in the vast majority of fisheries-conflict situations has never been studied scientifically. Similarly, where it has, scientific data have not always proven an impact. Assessing the impact of Cormorants is evidently more than a purely ‘scientific’

issue. There may well be strong evidence of Cormorant impact from other knowledge sources and, indeed, many stakeholder groups consider Cormorant impact to be proven based on their own information, knowledge and local experience.

A sceptical reader may conclude that investing in further biological research into Cormorant-fishery interactions is neither likely to be cost-effective nor particularly useful. However, this would be wrong. Cormorant ecology, from the local to the continental scale, is ultimately governed by the species' relationship with its environment and associated fish prey (see van Eerden *et al.* 2012). Here, environmental conditions will be paramount in that they affect such things as the presence or absence, productivity, abundance, quality and availability of fish species. There is thus clearly a lot more to be learned about these ecological relationships. Only with sound biological understanding of Cormorant- and fish ecology are we able to manage the species in the long-term (Wires *et al.* 2003) should this be necessary. There is still much to learn about the ecological relationships between Cormorants and fishes. Such knowledge will require dedicated, skilled fieldwork and carefully considered integration

of the data collected on both bird and fishes (e.g. see section 10.11). Detailed research work of the type described in the Field Manual will help our understanding of the ecological webs within which Cormorants and fish exist in a standardised way and will, to some degree at least, contribute to the mitigation of Cormorant-fishery conflicts and help to guide future research on what will undoubtedly remain a fascinating, if contentious, issue across Europe.

Besides a more realistic assessment of the biological factors concerning Cormorant impact there is also a more general need to consider other important elements (see also section 10.1 and 10.2). The word 'impact' means different things to different people (as does the term 'fisheries') and both quantitative and qualitative approaches to assessing it are essential. The 'frame' within which knowledge of Cormorant impact and associated data are to be interpreted also requires consideration. There are important spatial and temporal elements to this and a variety of scales over which impact can be examined. Choosing the 'correct' spatial and temporal scales within which impact is both biologically meaningful and meaningful to specific fisheries stakeholders may not always be easy. Similarly,

within these 'frames', careful consideration must be given to the criteria upon which any impact will be judged. Given the lack of agreement over whether there are impacts or not (partly, at least because the term means different things to different people) it is clear that this is an important area requiring further study. However, a qualitative approach (on social and economic grounds, say) may well give a more accurate assessment of Cormorant impact as experienced by fisheries stakeholders than the traditional biological approach.

The discussions above clearly recognise that scientific data alone will not provide all the answers to Cormorant-fishery conflicts and that a pragmatic approach is needed to managing them. Thus, in keeping with the wording of Article 2 of the Birds Directive, a more holistic approach to the issue of quantifying Cormorant impact should almost certainly include ecological, scientific and cultural requirements as well as economic and recreational ones in some justifiable and fair manner. Whilst this publication focuses primarily on ecological and scientific perspectives, much of INTERCAFE's work (see van Eerden *et al.* 2012, Russell *et al.* 2012, and Marzano & Carss 2012) has focussed on integrating them with others.

REFERENCES

Preface

Carss, D N, Bevan, R M, Bonetti, A, Cherubini, G, Davies, J, Doherty, D, EL Hili, A, Feltham, M J, Grade, N, Granadeiro, J P, Grémillet, D, Gromadska, J, Harari, Y N R A, Holden, T, Keller, T, Lariccia, G, Mantovani, R, McCarthy, T K, Mellin, M, Menke, T, Mirowska-Ibron, I, Müller, W, Musil, P, Nazirides, T, Suter, W, Trauttmansdorff, J, Volponi, S, and Wilson, B. 1997. Techniques for assessing Cormorant diet and food intake: towards a consensus view. *Supplemento alle Ricerche di Biologia della Selvaggina XXVI*: 197–230.

van Eerden, M R, Keller, T M, and Carss, D N. 2003. Preface. In: Keller, T M, Carss, D N, Helbig, A J, and Flade, M. *Cormorants: ecology and management. Proceedings of the 5th International Conference on Cormorants. Vogelwelt 124, Suppl.*

Introduction

Carss, D N (ed.). 2003. REDCAFE: Reducing the Conflict between Cormorants and Fisheries on a pan-European Scale — pan-European Overview. Report to the European Commission, contract number Q5CA-2000–31387, pp.169.

Carss, D N, and Marzano, M (eds.). 2005. REDCAFE: Reducing the Conflict between Cormorants and Fisheries on a pan-European Scale — Summary and National

Overviews. Report to the European Commission, contract number Q5CA-2000–31387, pp.374.

Cramp, S, and Simmons, K E L. 1980. *Handbook of the Birds of Europe, the Middle East and North Africa. The Birds of the Western Palearctic, Volume I Ostrich to Ducks.* Oxford University Press.

Gabriel, O, Lange, K, Dahm, E, and Wendt, T (eds.). 2005. *von Brandt's Fish Catching Methods of the World. 4th Edition,* Blackwell Publishing, Oxford.

Gilbert, G, Gibbons, D W, and Evans, J. 1998. *Bird Monitoring Methods,* Royal Society for the Protection of Birds, Sandy, UK.

Hoffmann, J. 1858. *Der Kormoran und dessen Verwendung zum Fischfang, Tafel 22.* In: C. Hoffmann (ed.) *Das Buch der Welt.* Hoffmannsche Verlagshandlung, Stuttgart.

Johnsgard, P A. 1993. *Cormorants, Darters and Pelicans of the World.* Smithsonian Institution Press, Washington.

Nelson, J B. 2005. *Pelicans, Cormorants and their Relatives. The Pelicaniformes.* Oxford University Press. New York.

van Eerden, M V, Koffijberg, K, and Platteeuw, M J. 2003. *Riding on the crest of the wave: possibilities and limitations for a*

*thriving population of migratory Cormorants *Phalacrocorax carbo* in man-dominated wetlands.* *Ardea* 83: 1–9.

van Eerden, M V, van Rijn, S, Volponi, S, Paquet, J-Y, and Carss, D N. 2012. *Cormorants and the European Environment: exploring Cormorant ecology on a continental scale.* COST Action 635 Final Report I. ISBN 978-1-906689-07-02.

Counting Cormorants

Blackburn, J. 1999. *Tree-nesting/inland Cormorant colonies.* *Ringers Bulletin* 10:12.

Bregnballe, T. 1996. *Reproductive Performance in Great Cormorants during Colony Expansion and Stagnation.* PhD thesis, 102 pp.

Bregnballe, T, and Gregersen, J. 2003. *Breeding success of Great Cormorants *Phalacrocorax carbo sinensis* in the Vorsø colony: variation among colony sections.* *Vogelwelt 124, Suppl.* 115–122.

del Hoyo, J, Elliott, A, and Sargatal, J (eds.). 1992. *Handbook of the Birds of the World, Vol. I ICBP,* Lynx Edicions, Barcelona.

Frederiksen, M, Bregnballe, T, and Reymond, A. 2003. *Estimating turnover at a staging site: how many Great Cormorants *Phalacrocorax carbo sinensis* used the Lake Geneva roost in autumn 1987.* *Vogelwelt 124,* 123–125.

- Harris, M P, and Forbes, R. 1987. The effect of date on counts of nests of Shags *Phalacrocorax aristotelis*. *Bird Study* 34: 187–190.
- Hughes, B, Sellers, R M, and Ekins, G R. 1998. Bird monitoring methods — Cormorant. In Gilbert, G, Gibbons, D W, and J Evans (eds.): *Bird Monitoring Methods: a manual of techniques for key UK species*. Royal Society for the Protection of Birds, Sandy, UK, pp.71–77.
- Im, B H, and H Hafner. 1984. Impact des oiseaux piscivores et plus particulièrement du Grand Cormoran (*Phalacrocorax carbo sinensis*) sur les exploitations piscicoles en Camargue, France. Station Biologique, La Tour du Valat.
- Im, B H, and H Hafner. 1985. Impact des oiseaux piscivores et plus particulièrement du Grand Cormoran (*Phalacrocorax carbo sinensis*) sur les exploitations piscicoles en Camargue. *Bull. Mens. Office Nat. Chasse* no. 94, 30–36; no. 95, 35–42.
- Kopciewicz, P, Stempniewicz, L, Nitecki, C, Bzoma, S, and Olszewska, A. 2003. Changes in the breeding success of Great Cormorants *Phalacrocorax carbo sinensis* in the expanding colony at Katy Rybackie (N Poland): effect of phenology and age of subcolony. *Vogelwelt* 124, Suppl.: 127–130.
- Korykakin, A, and Boyko, N S. 2005. The White-tailed Sea Eagle *Haliaeetus albicilla* and the Common Eider *Somateria mollissima* in the Gulf of Kandalaksha, White Sea. *Status of Raptor Populations in Eastern Fennoscandia*. Proceedings of the workshop, Kostomusksha, Karelia, Russia, November 8–10 2005.
- Krag, S M J. 2003. Variation in nest survival within a Great Cormorant *Phalacrocorax carbo sinensis* colony. *Vogelwelt* 124, Supplement: 131–137.
- Laursen, K, Frikke, J, and Kahlert, J. 2008. Accuracy of ‘total counts’ of waterbirds from aircraft in coastal waters. *Wildlife Biology* 14/2, 165–175.
- Lehikoinen, A. 2006. Cormorant in the Finish archipelago. *Ornis Fennica* 83: 34–66.
- Mayfield, H. 1961. Nesting success calculated from exposure. *Wilson Bull.* 73: 255–261.
- Mayfield, H. 1975. Suggestions for calculating nest success. *Wilson Bull.* 87, 456–466.
- Nelson, J B. 2005. Pelicans, Cormorants and their Relatives. *The Pelicaniformes*. Oxford University Press. New York.
- Newson, S E, and Bregnballe, T. 2003. Estimating reproductive success of Great Cormorants *Phalacrocorax carbo*: reliability and limitations of current methodology. *Vogelwelt* 124, Supplement, 143–148.
- Newson, S E, Hughes, B, Hearn, R, and Bregnballe, T. 2005. Breeding performance and timing of breeding of inland and coastal breeding Cormorants *Phalacrocorax carbo* in England and Wales. *Bird Study* 52, 10–17.
- Olver, M D, and Kuyper, M A. 1978. Breeding biology of the White-breasted Cormorant in Natal. *Ostrich* 49, 25–30.
- Pihl, S, and Frikke, J. 1992. Counting birds from aeroplane. In: Komdeur, J, Bertelsen, J, Cracknell, G. (eds.) *Manual for Aeroplane and Ship Surveys of Waterfowl and Seabirds*. IWRB Special Publication 19, 8–23.
- Quintana, F, and Yorio, P. 1998. Kelp Gull *Larus dominicanus* predation on an Imperial Cormorant *Phalacrocorax atriceps* colony in Patagonia. *Marine Ornithology* 26: 84–85.
- Rotella, J, Taper, M, Stephens, S, and Lindberg, M. 2007. Extending methods for modelling heterogeneity in nest survival data using generalized mixed models. *Studies in Avian Biology* 34, 32–44.
- Siegel-Causey, D, and Hunt, G L. 1981. Colonial defense behaviour in Double-crested and Pelagic Cormorants. *Ardea* 98: 522–581.
- van Eerden, M R, Zijlstra, M, and Munsterman, M J. 1991. Factors determining breeding success in Cormorants *Phalacrocorax carbo sinensis*. In: van Eerden, M R, and M, Zijlstra (eds.): *Proceedings workshop 1989 on Cormorants Phalacrocorax carbo*. Rijkswaterstaat Directorate Flevoland, Lelystad, The Netherlands, pp.67–73.
- van Rijn, S, van Eerden, M R, and Zijlstra, M. 2003. Body condition of young Great Cormorants *Phalacrocorax carbo sinensis* as an indicator of colony performance. *Vogelwelt* 124, Suppl., 167–171.

- Walsh, P M, Halley, D J, Harris, M P, del Nevo, A, Sim, I M W, and Tasker, M L. 1995. Seabird Monitoring Handbook for Britain and Ireland. JNCC/RSPB/ITE/Seabird Group, Peterborough.
- Worden, J, Hall, C, and Cranswick, P. 2004. Cormorant *Phalacrocorax carbo* in Great Britain: results of the January 2003 roost survey. The Wildfowl & Wetlands Trust, Slimbridge.
- Wright, G A. 2003. Turnover in a wintering Cormorant population: implications for management. In: Cowx, I G (ed.) Interactions Between Fish and Birds: implications for management, pp.345–353. Fishing News Books, Oxford.
- Cormorant diet, food and energy intake
- AFORO online otolith database: www.cmima.csic.es/aforo/index.jsp
- Black, J A. 1964. A further look at Cormorants. Salmon and Trout magazine 172: 166–180.
- Brugger, K E. 1993. Digestibility of three fish species by Double-crested Cormorants. Condor 95: 25–32.
- Butler, P J. 1993. To what extent can heart rate be used as an indicator of metabolic rate in free-living marine mammals? Symposia of the Zoological Society of London 66: 317–332.
- Butler, P J, Green, J A, Boyd, I L, and Speakman, J R. 2004. Measuring metabolic rate in the field: the pros and cons of the doubly labelled water and heart rate methods. Functional Ecology 18: 168–183.
- Carss, D N (ed.). 2003. Reducing the Conflict Between Cormorants and Fisheries on a pan-European Scale. REDCAFE Overview. Report to European Commission, contract number Q5CA-2000–31387, pp.169.
- Carss, D N, Bevan, R M, Bonetti, A, Cherubini, G, Davies, J, Doherty, D, EL Hili, A, Feltham, M J, Grade, N, Granadeiro, J P, Grémillet, D, Gromadska, J, Harari, Y N R A, Holden, T, Keller, T, Lariccia, G, Mantovani, R, McCarthy, T K, Mellin, M, Menke, T, Mirowska-Ibron, I, Müller, W, Musil, P, Nazirides, T, Suter, W, Trauttmansdorff, J, Volponi, S, and Wilson, B. 1997. Techniques for assessing Cormorant diet and food intake: towards a consensus view. Supplemento alle Ricerche di Biologia della Selvaggina XXVI: 197–230.
- Carss, D N, and Ekins, G R. 2002. Further European integration: mixed sub-species colonies of Great Cormorants *Phalacrocorax carbo* in Britain — colony establishment, diet, and implications for fisheries management. Ardea 90 (1): 23–41.
- Carss, D N, and Marquiss, M. 1997. The diet of Cormorants *Phalacrocorax carbo* in Scottish freshwaters in relation to feeding habitats and fisheries. Ekologia Polska 45 (1): 207–222.
- Carss, D N, and Marzano, M (eds.). 2003. Reducing the conflict between Cormorants and fisheries on a pan-European scale. REDCAFE Summary & National Overviews. Report to European Commission, contract number Q5CA-2000–31387, pp.374.
- Davies, J M, and Feltham, M J. 1996. The diet of wintering Cormorants *Phalacrocorax carbo* L. in relation to angling catches on a coarse river fishery in north-west England. In: Greenstreet, S P, and Tasker, M L (eds), pp.106–110, Aquatic Predators and their Prey, Blackwell Scientific Publications, Oxford.
- Dirksen, S, Boudewijn, T J, Noorhuis, R, and Marteiijn, E C L. 1995. Cormorants *Phalacrocorax carbo sinensis* in shallow eutrophic freshwater lakes: prey choice and fish composition in the non-breeding period and effects of large-scale fish removal. Ardea 83(1): 167–184.
- Enstipp, M R, Grémillet, D, and Lorentsen, S-H. 2005. Energetic costs of diving and thermal status in European shags (*Phalacrocorax aristotelis*). Journal of Experimental Biology 208: 3451–3461.
- Enstipp, M R, Grémillet, D, and Jones, D R. 2006a. The effects of depth, temperature and food on the diving energetics of Double-crested Cormorants (*Phalacrocorax auritus*). Journal of Experimental Biology 209: 845–859.
- Enstipp, M R, Daunt, F, Wanless, S, Humphreys, E M, Hamer, K C, Benvenuti, S, and Grémillet, D. 2006b. Foraging energetics of North Sea birds confronted with fluctuating prey availability. In: Boyd, I L, Wanless, S, and Camphuysen, C J (eds.) Top predators in Marine Ecosystems (Symposium of the Zoological Society London). Cambridge: Cambridge University Press.
- Enstipp, M R, Grémillet, D, and Jones, D R. 2007. Investigating

- the functional link between prey abundance and seabird predatory performance. *Marine Ecology Progress Series* 331: 267–279.
- Enstipp, M R, Grémillet, D, and Jones, D R. 2008. Heat increment of feeding in double-crested Cormorants (*Phalacrocorax auritus*) and its potential for thermal substitution. *Journal of Experimental Biology* 211: 49–57.
- Feltham, M J. 1990. The diet of red-breasted mergansers *Mergus serrator* during the smolt run in northeast Scotland: the importance of salmon *Salmo salar* smolts and parr. *Journal of Zoology of London*, 222: 285–292.
- Goldstein, D L. 1988. Estimates of daily energy expenditure in birds: the time-energy budget as an indicator of laboratory and field studies. *American Zoologist*. 28: 829–844.
- Govedič, M, Janzekovic, F, and Kos, I. 2002. The diet of Great Cormorants *Phalacrocorax carbo* on the Sava river between Ljubljana and Zagorje (Slovenia). *Acrocephalus* 23 (110–111): 5–20.
- Grémillet, D, and Schmid, D. 1993. Zum Nahrungsbedarf des Kormorans *Phalacrocorax carbo sinensis*. Gutachten im Auftrag des Ministeriums für Natur, Umwelt und Landesentwicklung des Landes Schleswig-Holstein. Universität Kiel. 55pp.
- Grémillet, D, Schmid, D, and Culik, B M. 1995. Energy requirements of breeding great Cormorants *Phalacrocorax carbo sinensis*. *Marine Ecology Progress Series* 121: 1–9.
- Grémillet, D, Storch, S, and Peters, G. 2000. Determining food requirements in marine top predators: a comparison of three independent techniques in great Cormorants, *Phalacrocorax carbo carbo*. *Canadian Journal of Zoology* 78: 1567–1579.
- Grémillet, D, Wright, G, Lauder, A, Carss, D N, and Wanless, S. 2003. Modelling the daily food requirements of wintering great Cormorants: a bioenergetics tool for wildlife management. *Journal of Applied Ecology* 40: 266–277.
- Grémillet, D, Chauvin, C, Wilson, R P, Le Maho, Y, and Wanless, S. 2005a. Unusual feather structure allows partial plumage wettability in diving great Cormorants (*Phalacrocorax carbo*). *Journal of Avian Biology* 36: 1–7.
- Grémillet, D, Kuntz, G, Woakes, A J, Gilbert, C, Robin, J-P, Le Maho, Y, and Butler, P J. 2005b. Year-round recordings of behavioural and physiological parameters reveal the survival strategy of a poorly insulated diving endotherm during the Arctic winter. *Journal of Experimental Biology* 208: 4231–4241.
- Hald-Mortensen, P. 1997. Does Cormorant food tell more about fish than Cormorants? *Supplemento alle Ricerche Biologia della Selvaggina* XXVI: 173–180.
- Hennemann, W. 1985. Energetics, behavior and the zoogeography of Anhingas and Double-crested Cormorants. *Ornis Scand.* 16: 319–323.
- Hislop, J R G, Harris, M P, and Smith, J G M. 1991. Variation in the calorific value and total energy content of the lesser sandeel (*Ammodytes marinus*) and other fish preyed on by seabirds. *Journal of Zoology of London* 224: 501–517.
- Horoszewicz, L. 1960. The value of lower pharyngeal arches as species criteria for defining fish of the Cyprinid family. *Roczniki Nauk Rolniczych* 75 b–2: 237–258.
- Keller, T. 1995. Food of Cormorants *Phalacrocorax carbo sinensis* wintering in Bavaria, southern Germany. *Ardea* 83 (1): 185–192.
- Keller, T M, and Visser, G H. 1999. Daily energy expenditure of Great Cormorants *Phalacrocorax carbo sinensis* wintering at Lake Chiemsee, Southern Germany. *Ardea* 87: 61–69.
- Lifson, N, Gordon, J B, and McClintock, R. 1955. Measurement of total carbon dioxide production by means of D₂¹⁸O. *Journal of Applied Physiology* 7: 704–710.
- Libois, R M, and Hallet-Libois, C. 1988. Éléments pour l'identification des restes crâniens des poissons dulçaquicoles de Belgique et du nord de France. 2: Cypriniformes. Fiches d'ostéologie animale pour l'archéologie. Serie A: Poissons, n°4:24.
- Libois, R M, Hallet-Libois, C, and Rosoux, R. 1987. Éléments pour l'identification des restes crâniens des poissons dulçaquicoles de Belgique et du nord de France. I: Anguilliformes, Gastérostéiformes, Cyprinidontiformes et Perciformes. Fiches d'ostéologie animale pour l'archéologie. Serie A: Poissons, n°3:15.

- Leopold, M F, Damme van, C J G, Philippart, C J M, and Winter, C J N. 2001. Otoliths of North Sea Fish. ETI & UNESCO. The World Biodiversity Database. CD-ROM.
- Lovvorn, J R, and Jones, D R. 1991. Body mass, volume, and buoyancy of some aquatic birds, and their relation to locomotor strategies. *Canadian Journal of Zoology* 69: 2888–2892.
- März, R. 1987. *Gewöll- und Rupfungskunde*. Akademie Verlag, Berlin.
- Mehner, T. 1992. Bestimmung von Fischresten aus Fraßresten der Vögel. *Der Falke* 92/39: 56–59.
- Pennycuik, C J. 1989. *Bird flight performance: a practical calculation manual*. Oxford University Press, Oxford.
- Petrova, G, and Zivkov, M. 1989. A contribution to the methodology of the study of predator fishes food. *Vets.cs. Spolec. zool.* 53: 280–290.
- Przyblski, M. 1996. Variation in fish growth characteristics along river course. *Hydrobiologia* 325: 39–46.
- Ricker, W E. 1979. Growth rates and models. In: *Fish Physiology* Vol. VIII. 677–743. Academic Press.
- Ridgway, M S. 2010. A review of estimates of daily energy expenditure and food intake in Cormorants (*Phalacrocorax* spp.) *Journal of Great Lakes Research* 36: 93–99.
- Russell, I C, Cook, A C, Kinsman, D A, Ives, M J, and Lower, N J. 2003. Stomach content analysis of Great Cormorants *Phalacrocorax carbo* at some different fishery types in England and Wales. *Vogelwelt* 124, Supplement 255–259.
- Rutte, E. 1962. Schlundzähne von Süßwasserfischen. *Paläontographica*, Abt. 120: 165–212.
- Schulz-Mirbach, T, and Reichenbacher, B. 2006. Reconstruction of Oligocene and Neogene fresh water fish faunas — an actualistic study on cypriniform otoliths. *Acta Palaeontologica Polonica* 51 (2): 282–304.
- Speakman, J R. 1997. *Doubly Labelled Water: theory and practice*. Chapman & Hall, London.
- Storch, S, Grémillet, D, and Culik, B M. 1999. The telltale heart: a non-invasive method to determine the energy expenditure of incubating great Cormorants *Phalacrocorax carbo carbo*. *Ardea* 87: 207–215.
- Strod, T, Izhaki, I, Arad, Z: Weihs, D, and Kazir, G. 2003. Cormorants *Phalacrocorax carbo* swallow fish under water. *Vogelwelt* 124, Supplement: 270.
- Trauttmansdorff, J. 2003. Analysis of Great Cormorant *Phalacrocorax carbo sinensis* stomach contents from different areas of Austria and Liechtenstein. *Vogelwelt* 124, Supplement 271–276.
- Wilson, R P, and Culik, B M. 1993. Activity-specific metabolic rates from double-labelled water studies: are activity costs underestimated? *Ecology* 74: 1285–1287.
- Wise, M H. 1980. The use of fish vertebrae in scats for estimating prey size in otters and mink. *Journal of Zoology of London* 192: 25–31.
- Veldkamp, R. 1995. Diet of Cormorants *Phalacrocorax carbo sinensis* at Wanneperveen, The Netherlands, with special reference to Bream *Abramis brama*. *Ardea* 83 (1): 143–156.
- Zijlstra, M, and van Eerden, M R. 1995. Pellet production and the use of otoliths in determining the diet of Cormorants *Phalacrocorax carbo sinensis*: trials with captive birds. *Ardea* 83: 123–131.
- [Sexing, ageing and measuring Cormorants](#)
- Koffijberg, K, and M R van Eerden. 1995. Sexual dimorphism in the Cormorant *Phalacrocorax carbo sinensis*: possible implications for differences in structural size. *Ardea* 83, 37–46.
- Millington, R. 2005). Identification of North Atlantic and Continental Cormorants. *Birding World* 18, 3, 112–123.
- Nelson, J B. 2005. *Pelicans, Cormorants, and their Relatives. The Pelicaniformes*. Oxford University Press. New York.
- Newson, S E, B, Hughes, I C, Russell, G R, Ekins, and R M, Sellers. 2004. Sub-specific differentiation and distribution of great Cormorants *Phalacrocorax carbo* in Europe. *Ardea* 93: 3–10.
- Platteeuw, M, Koffijberg, K, and Dubbeldam, W. 1995. Growth of Cormorant *Phalacrocorax carbo sinensis* chicks in relation to brood size, age ranking and parental fishing effort. *Ardea* 83, 235–245.

- van Eerden, M R, and Munsterman, M J. 1986. Importance of the Mediterranean for wintering Cormorants *Phalacrocorax carbo sinensis*. In: Medmarvai & Monbailliu (eds.) Mediterranean Marine Avifauna, NATO Asi Series, Vol. G12:123–141. Springer Verlag, Berlin.
- van Eerden, M R, and Munsterman, M. 1995. Sex and age dependent distribution in wintering Cormorants *Phalacrocorax carbo sinensis* in Western Europe. *Ardea* 83, 285–297.
- Movements**
- Bregnballe, T. 1999. Seasonal and geographical variation in net-entrapment of Danish Great Cormorants *Phalacrocorax carbo sinensis*. *Dansk Ornitologisk Forenings Tidsskrift* 93: 247–254.
- Bregnballe, T. 2006. Age-related fledgling production in Great Cormorants *Phalacrocorax carbo*: influence of individual competence and disappearance of phenotypes. *Journal of Avian Biology* 37(2): 149–157.
- Bregnballe, T, Frederiksen, M, and Gregersen, J. 1997. Seasonal distribution and timing of migration of Cormorants *Phalacrocorax carbo sinensis* breeding in Denmark. *Bird Study* 44: 257–276.
- Bregnballe, T, Frederiksen, M, and Gregersen, J. 2006. Effects of distance to wintering area on arrival date and breeding performance in Great Cormorants *Phalacrocorax carbo*. *Ardea* 94(3): 619–630.
- Fiedler, W. 1999. Kormorane *Phalacrocorax carbo* als Durchzügler und Wintergäste in Süddeutschland und Österreich — eine Ringfundanalyse 1998–1999. *Ornithologischer Beobachter* 96, 183–192.
- Frederiksen, M, and Bregnballe, T. 2000. Evidence for density-dependent survival in adult Cormorants from a combined analysis of recoveries and resightings. *Journal of Animal Ecology* 69: 737–752.
- Frederiksen, M, Bregnballe, T, van Eerden, M, van Rijn, S, and Lebreton, J D. 2002. Site fidelity of wintering Cormorants *Phalacrocorax carbo sinensis* in Europe. *Wildlife Biology* 8/4, 241–250.
- Galván, I. 2005. Migration strategies of the Great Cormorant wintering inland in Spain. *Waterbirds* 28 (3): 301–307.
- Hénaux, V, Bregnballe, T, and Lebreton, J B. 2007. Dispersal and recruitment during population growth in a colonial bird, the great Cormorant *Phalacrocorax carbo sinensis*. *J. Avian Biol.* 38: 44–57.
- Paquet, J Y, Dermien, F, Lacroix, P, Lucas, P, and Pourignaux, F. 2003. Year-to-year site-fidelity of wintering and migrating Great Cormorants *Phalacrocorax carbo* in Belgian Meuse valley. *Vogelwelt* 124, Suppl.: 53–60.
- Retter, M. 2000. Origin and migration pattern of Cormorants (*Phalacrocorax carbo sinensis*) in the Upper Rhine area — an analysis of colour-ring sightings of wintering and staging birds. *Naturschutz südl. Oberrhein*, 3: 1–11.
- Reymond, A, and Zuchuat, O. 1995a. Axial migration routes in Cormorants *Phalacrocorax carbo* passing through or wintering in Switzerland. *Ardea*, 83: 275–280.
- Reymond, A, and Zuchuat, O. 1995b. Perch fidelity of Cormorants *Phalacrocorax carbo* outside the breeding season. *Ardea*, 83: 281–284.
- van Eerden, M R, and Munsterman, M J. 1986. Importance of the Mediterranean for wintering Cormorants *Phalacrocorax carbo sinensis*. In: Medmarvais & Monbailliu (eds.) Mediterranean Marine Avifauna, NATO Asi Series, Vol. G12:123–141. Springer Verlag, Berlin.
- van Eerden, M R, and Munsterman, M J. 1995. Sex and age dependent distribution in wintering Cormorants *Phalacrocorax carbo sinensis* in Western Europe. *Ardea* 83:285–297.
- van Rijn, S, and van Eerden, M. 2007. Recent population changes of Cormorants *Phalacrocorax carbo* in the IJsselmeer area, the Netherlands. *Aves*, 44 (3): 151–154.
- Sackl, P, and Zuna-Kratky, T. 2004. Herkunftsgebiete, Wanderrouten und Zugablauf in Österreich rastender und überwinterner Kormorane (*Phalacrocorax carbo sinensis*) — eine Ringfundanalyse. *Egretta* 47: 39–65.
- Yésou, P. 1995. Individual migration strategies in Cormorants *Phalacrocorax carbo* passing through or wintering in Western France. *Ardea*, 83: 267–274.
- Other relevant literature**
- Jenard, P. 2007. Suivi détaillé de la reproduction du Grand Cormoran (*Phalacrocorax carbo*) dans les

colonies d'Hensies en 2005 et comparaison avec les résultats de 1999. Aves 44 (2), 79–90.

Paquet, J-Y, Malengreau, A, and Simar, J. 2007. Dispersion des Grands Cormorans (*Phalacrocorax carbo*) de la colonie d'Hensies (Z.h.i.b. des marais d'Harchies): premiers résultats du baguage couleur. Aves 44 (3), 145–148.

Sandor, D A, Kiss, J B, and Domsa, C. 2009. The importance of Northern Dobrogea in the migration of Great Cormorant (*Phalacrocorax carbo*). Scientific Annals of the Danube Delta Inst., Tulcea, 15: 41–46.

Working with Fishes

Carss, D N, Marquiss, M, and Lauder, A W. 1997. Cormorant *Phalacrocorax carbo carbo* predation at a major trout fishery in Scotland. Supplemento alle Ricerche di Biologia della Selvaggina Volume XXVI (No. 1): 281–294.

Cowx, I G. 1999. An appraisal of stocking strategies in the light of developing country constraints. Fisheries Management and Ecology, 6: 21–34.

Carvalho, G R, and Cross, T. 1998. Enhancing fish production through introductions and stocking: genetic perspectives. In: I G, Cowx (ed.) Stocking and Reintroduction of Fish. Fishing News Books, Blackwell Scientific Publications, Oxford, pp.329–337.

Environment Agency (undated) Stocking Fish: a guide for fishery owners and anglers. Environment Agency, Kidderminster, UK.

Available at: http://www.environment-agency.gov.uk/static/documents/Business/stocking_eng_172017.pdf

Hart, P J, and Reynolds, J D. 2002. Handbook of Fish Biology and Fisheries (Volume 1), Blackwell Scientific Publications, Oxford, 432pp.

Hassan, R, Scoles, R, and Ash, N. 2005. The Millennium Ecosystem Assessment Series; v.1 Current State and Trends. Island Press, Washington, 917pp.

Hickley, P. 1994. Stocking and introduction of fish — a synthesis. In: I G, Cowx (ed.) Rehabilitation of Freshwater Fisheries, pp. 247–254. Fishing News Books, Blackwell Scientific Publications, Oxford.

Kottelat, M, and Freyhof, J. 2007. Handbook of European Freshwater Fishes. Publications Kottelat, Switzerland, 646pp.

Marquiss, M, Carss, D N, Armstrong, J D, and Gardiner, R. 1998. Fish-eating Birds and Salmonids in Scotland. Report to The Scottish Office Agriculture, Environment and Fisheries Department. Scottish Office, Edinburgh, 156pp.

McGinnity, P, Prodohl, P, Ferguson, A, Hynes, R, O'Maoileidigh, N, Baker, N, Cotter, D, O'Hea, B, Cooke, D, Rogan, G, Taggart, J, and Cross, T. 2003. Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farmed salmon. Proceedings of the Royal Society of London, Series B: Biological Sciences, 270: 2443–2450.

Pitcher, T J (ed.). 1993. Behaviour of Teleost Fishes. Second Edition, Chapman & Hall, London.

Wheeler, A. 1978. Key to the Fishes of Northern Europe. Frederick Warne & Co. Ltd.

Wootton, R J (ed.). 1990. Ecology of Teleost Fishes. Chapman & Hall, London.

Estimating abundance of fish species

Appelberg, M. 2000. Swedish standard methods for sampling freshwater fish with multi-mesh gillnets. Fiskeriverket Inf. 2000, 1.

European Committee for Standardisation (CEN) (2002) European Standard (EN) 14011: Water quality — sampling of fish with electricity. Ref. No. prEN 14011:2002 E. CEN. 16 pages.

European Committee for Standardisation (CEN) (2004) European Standard (EN) 14962: Water quality — Guidance on the scope and selection of fish sampling methods. Ref.No. prEN 14962: 2004:E. CEN. 25 pages.

European Committee for Standardisation (CEN) (2005) European Standard (EN) 14757: Water quality — Sampling of fish with multi-mesh gillnets. Ref. No. prEN 14757:2005 E. CEN. 27 pages.

Cowx, I G. 1983. Review of the methods for estimating fish population size from survey removal data. Fisheries Management 14:67–82.

Cowx, I G. 1991. Catch effort sampling strategies: conclusions

and recommendations for management. In: *Catch Effort Sampling Strategies* (Ed. I.G. Cowx). Fishing News Books, Blackwell Scientific Publications, Oxford.

Cowx, I G. 1995. Fish stock assessment — biological basis for sound ecological management. In: Harper, D, and Ferguson, A (eds.): *Biological Basis for River Management*. Wiley and Son, London: 375–388.

Cowx, I G. 1996. *Stock Assessment in Inland Fisheries*. Fishing News Books, Blackwell Scientific Publications, Oxford, 513pp.

De Lury, D. 1947. On the estimation of biological populations. *Biometrics* 3: 145–167.

Gabriel, O, Lange, K, Dahm, E, and Wendt, T (eds.). 2005. *von Brandt's Fish Catching Methods of the World*. 4th Edition. Blackwell Publishing, Oxford.

Haunschmid, R. 2004. *Dynamik des Bachforellenbestandes an drei Untersuchungsstrecken der Kleinen Mühl (OÖ)*. Dissertation an der Universität Salzburg. 131pp.

Hemingway, K L, and Elliot, M. 2002. *Fishes in Estuaries*. Blackwell Science. Oxford.

Hilborn, R, and Walters, C J. 1992. *Quantitative Fisheries Stock Assessment — choice and dynamics*. Chapman and Hall, N.Y. London. 570pp.

Jennings, S, Kaiser, M J, and Reynolds, J D. 2001. *Marine Fisheries Ecology*. Blackwell Science. Oxford.

Kieffer, J D, and Colgan, P W. 1992. The role of learning in fish behaviour. *Reviews in Fish Biology and Fisheries* 2, 125–143.

Magurran, A E. 1990a. The adaptive significance of schooling as anti-predator defence in fish. *Annales Zoologici Fennici* 27, 51–66.

Magurran, A E. 1990b. The inheritance and development of minnow anti-predator behaviour. *Animal Behaviour* 39, 834–842.

Murphy, B R, and Willis, D W (eds.). 1996. *Fisheries Techniques*. Bethesda: American Fisheries Society.

Nielsen, L A, and Johnson, D L (eds.). 1983. *Fisheries Techniques*. The American Fisheries Society, Southern Printing Company, Virginia, USA.

Reynolds, J B. 1983. Electro-fishing. In: *Fisheries Techniques* (eds: Nielsen, L A, and Johnson, D L) American Fisheries Society Bethesda, Maryland. 468pp.

Seber, G A F, and Le Cren, E D. 1967. Estimating population parameters from the catches large relative to the population. *Journal of Animal Ecology* 36, 631–643.

Winfield, I J, Fletcher, J M, and James, J B. 2007. Seasonal variability in the abundance of Arctic charr (*Salvelinus alpinus* (L.)) recorded using hydroacoustics in Windermere, UK and its implications for survey design. *Ecology of Freshwater Fish* 16: 64–69.

Winfield, I J, Fletcher, J M, James, J B, and Bean, C W. 2009. Assessment of fish populations in

still waters using hydroacoustics and survey gill netting: experiences with Arctic charr (*Salvelinus alpinus*) in the UK. *Fisheries Research* 96: 30–38.

Indicators of Cormorant damage

Beveridge, M E M. 1988. Problems caused by birds at inland waters and freshwater fish farms. EIFAC Tech. Rep. 51:34–73.

Callaghan, D A, Kirby, J S, and Bell, M C. 1994. An assessment of Cormorant *Phalacrocorax carbo* occupancy and impact at stillwater game fisheries in England and Wales. Report to the Association of Stillwater Game Fishery Managers, WWT, Slimbridge.

Carss, D N. 1990. Beak-prints help in war against aerial invaders. *Fish Farmer*, November-December 1990: 46–48.

Carss, D N. 1993. Cormorants *Phalacrocorax carbo* at cage fish farms in Argyll, western Scotland. *Seabird* 15: 38–44.

Carss, D N, and Marquiss, M. 1991. Avian predation at farmed and natural fisheries. Interactions between fisheries and the environment. Proceedings of the Institute of Fisheries Management 22nd annual study course.

Carss, D N, and Marquiss, M. 1995. Fish-eating birds: perceptions and realities. British Trout Farming Conference, Sparsholt, September 1995.

Cornelisse, K J, and Christensen, K D. 1993. Investigation of a cover net designed to reduce southern cormorant (*Phalacrocorax*

- carbo sinensis*) fisheries depredation in a pound net. ICES J. Mar. Sci., 50:279–284.
- Dieperink, C. 1993. Fisheries depredation caused by cormorant (*Phalacrocorax carbo sinensis* Shaw). EIFAC Workshop, Starnberg, Germany, July 1993 (abstract only).
- Engström, H. 1998. Conflicts between cormorants *Ph. c. sinensis* and fishery in Sweden. Nordic Journal of Freshwater Research 74:148–155.
- Moerbeek, D J, van Dobben, W H, Osiek, E R, Boere, G C, and Bungenberg De Jong, C M. 1987. Cormorant damage prevention at a fish farm in the Netherlands. Biological Conservation 39: 23–38.
- Musil, P, Janda, J, and De Nie, W. 1995. Changes in abundance and foraging habitat selection in Cormorant (*Phalacrocorax carbo*) in the south Bohemia. Ardea 83: 247–254.
- Musil, P, and Janda, J. 1997. Habitat selection by Cormorant (*Phalacrocorax carbo*) on South Bohemian fishponds. Ekologia Polska 45: 173–180.
- Ranson, K, and Beveridge, M C M. 1983. Raiders from the skies. Bird predation at a freshwater cage farm. Fish Farmer 6: 22–23.
- Russell, I C, Dare, P J, Eaton, D R, and Armstrong, J A. 1996. Assessment of the problem of fish-eating birds in inland fisheries in England and Wales. Report to the Ministry of Agriculture, Fisheries and Food (MAFF Project VC0104), 130pp.
- Seiche, K, and Wünsche, A. 1996. Kormoran (*Phalacrocorax carbo* L.) und Graureiher (*Ardea cinerea* L.) im Freistaat Sachsen. Freistaat Sachsen, Staatsministerium für Umwelt und Landesentwicklung, Dresden. 102 pp.
- Staub, E, Krämer, A, Müller, R, Ruhlé, Ch, and Walter, J. 1992. Einfluss des Kormorans (*Phalacrocorax carbo*) auf Fischbestände und Fangerträge in der Schweiz. Schriftenreihe Fischerei, No. 50:1–131.
- Staub, E, and Ball, R. 1994. Effects of cormorant predation on fish populations of inland waters. Working document for 18th Session of EIFAC, and Report of the EIFAC Working Party, Starnberg, Germany, July 1993, EIFAC/ XVIII/94/Inf.8 Rev. May 1994.
- Suter, W. 1995. Are cormorants *Phalacrocorax carbo* wintering in Switzerland approaching carrying capacity? An analysis of increase patterns and habitat choice. Ardea, 83:255-266.
- van Dobben, W.H. 1952. The food of the cormorant in The Netherlands. Ardea 40:1-63.
- [Attempting to integrate Cormorant and fish data](#)
- Begon, M, Harper, J L, and Townsend, C R. 1996. Ecology. 3rd edition, Blackwell Science.
- Carpenter, S R. 1993. Statistical analysis of the ecosystem experiments. In: Carpenter, S R, and Kitchell, J F. (eds.) The Trophic Cascade in Lakes, pp.26–42. Cambridge Studies in Ecology, Cambridge University Press.
- Carss, D N, Bell, S, and Marzano, M. 2009. Competing and coexisting with Cormorants: ambiguity and change in European wetlands. In: Heckler, S. (ed.) Landscape, Process and Power: re-evaluating traditional environmental knowledge, pp.99–121. Berghan Books, Oxford.
- Cherrett, J M. 1989. Ecological concepts: the contribution of ecology to an understanding of the natural world. Volume 29 of Symposium of the British Ecological Society, Blackwell Scientific Publications.
- Crawley, M J. 1992. Population dynamics of natural enemies and their prey. In: Crawley, M J. (ed.) Natural Enemies: the population biology of predators, parasites and diseases, pp.40–89. Blackwell Scientific Publications.
- Dalton, C M, Ellis, D, and Post, D M. 2009. The impact of double-crested Cormorant (*Phalacrocorax auritus*) predation on anadromous alewife (*Alosa pseudoharengus*) in south-central Connecticut, USA. Canadian Journal of Fisheries and Aquatic Science 66: 177–186.
- Feltham, J M, Davies, J M, Wilson, B R, Holden, T, Cowx, I G, Harvey, J P, and Britton, J R. 1999. Case studies of the impact of fish-eating birds on inland fisheries in England and Wales. Report to the Ministry of Agriculture, Fisheries and Food, 144pp.
- Kitchell, J F, and Carpenter, S R. 1993. Cascading trophic interactions. In: Carpenter, S R, and Kitchell, J F. (eds.) The Trophic Cascade in Lakes, pp.1–14. Cambridge Studies in Ecology, Cambridge University Press.

- Krebs, C J. 1989. *Ecological Methodology*. Harper Collins.
- Krebs, C J. 2001. *Ecology: the experimental analysis of distribution and abundance*. 5th Edition, Benjamin Cummings, San Francisco.
- Marquiss, M, and Carss, D N. 1994. *Avian Piscivores: basis for policy*. National Rivers Authority, Bristol.
- Marquiss, M, and Carss, D N. 1997. Fish-eating birds and fisheries. *BTO News* 210/11: 6–7. British Trust for Ornithology.
- Marquiss, M, Carss, D N, Armstrong, J D, and Gardiner, R. 1998. *Fish-eating birds and Salmonids in Scotland*. Report to The Scottish Office Agriculture, Environment and Fisheries Department. Scottish Office, Edinburgh.
- Marzano, M, and Carss, D N (eds). 2012. *Essential social, cultural and legal perspectives on Cormorant-fisheries conflicts*. INTERCAFE COST Action 635 Final Report IV. ISBN 978-1-906698-11-9.
- Pitcher, T J (ed.). 1993. *Behaviour of Teleost Fishes*. 2nd Edition, Chapman & Hall, London.
- Raffaelli, D, and Hawkins, S. 1999. *Intertidal Ecology*. Kluwer Academic Publishers.
- Russell, I C. 2006. *Definitions*. In: Carss, D N, and Marzano, M. (eds.) *Commercial Carp Aquaculture*. INTERCAFE meeting report, Saxony, Germany, September 2005: 10–14.
- Russell, I C, Dare, P J, Eaton, D R, and Armstrong, J D. 1996. *Assessment of the problem of fish-eating birds in inland fisheries in England and Wales*. Report to the Ministry of Agriculture, Fisheries and Food. Directorate of Fisheries Research, Lowestoft, 130pp.
- van Eerden, M, van Rijn, S, Volponi, S, Paquet, J-Y and Carss, D. 2012. *Cormorants and the European Environment: exploring Cormorant status and distribution on a continental scale*. INTERCAFE COST Action 635 Final Report I. ISBN 978-1-906698-07-2
- Wires, L R, Carss, D N, Cuthbert, F J, and Hatch, J J. 2003. *Trans-continental connections in relation to Cormorant-fisheries conflicts: perceptions and realities of a 'bête noire' (black beast) on both sides of the Atlantic*. *Vogelwelt* 124, Supplement: 398–400.
- Wootton, R J (ed.). 1990. *Ecology of Teleost Fishes*. Chapman & Hall, London.

APPENDIX ONE: RELATED CORMORANT SPECIES IN EUROPE

Cramp, S, and Simmons, K E L. 1977. *Handbook of the birds of Europe, the Middle East and North Africa. The birds of the Western Palaearctic. Volume 1:216–219*. Oxford University Press.

Johnsgard, P A. 1993. *Cormorants, Darters and Pelicans of the World*. Smithsonian Institution Press, Washington.

Nelson, B J. 2005. *Pelicans, Cormorants and their Relatives — the Pelecaniformes*. Oxford University Press, Oxford.

11 APPENDIX ONE: RELATED CORMORANT SPECIES IN EUROPE

The most abundant cormorant species in Europe is the Great Cormorant *Phalacrocorax carbo*, which has two subspecies or races (see chapter 2). However, two other cormorant species occur throughout Europe, the Pygmy Cormorant (*Phalacrocorax pygmeus*) and the European Shag (*Phalacrocorax aristoteles*) with two subspecies (*Ph. a. aristotelis* and *Ph. a. desmarestii*). The geographical ranges of these three cormorants overlaps in Europe and there is thus potential for some confusion between them. This Appendix provides a summary of information about these two other European cormorant species (and mentions differences between them and *P. carbo*) and is taken from three publications (Cramp & Simmons 1977, Johnsgard 1993, and Nelson 2005).

11.1 Pygmy Cormorant (*Phalacrocorax pygmeus*)

This is the smallest of the three species of European cormorants and has a distinctly thinner and shorter bill. In breeding plumage the neck and head plumage is a rich brownish black, the body black with greenish iridescence and some white spots not present in other seasons. Immatures are distinguishable from immature European Shags by more extensive

light colouration on their underside and from Great Cormorants by their smaller size. Overall, Pygmy Cormorants are around half the size of Great Cormorants.

11.1.1 Sex & age

Adults: in autumn and early winter, the head, upper half of neck, and the breast are dark brown, sometimes looking black with a brown tinge. There is some black on the forepart of the head, variable white on the throat and around the



Figure 11.1 Adult Pygmy Cormorant. Photo courtesy of R Sauli.

eyes, black scapulars and upper wing-coverts with a grey tinge and darker edges giving scaled appearance. Otherwise, plumage is black with a green sheen above and light brown below. The bill is black-brown, the bare facial skin is tinged pink, and the feet are blackish. In summer (moult starts in December), the head and upper neck are strongly tinged red-brown, becoming nearly black before breeding, with short crest and scattering of white filoplumes over head, neck. The underbody and upper tail-coverts are black and the scapulars and upper wing-coverts greyer with a more marked scaled appearance. Females are slightly duller than males.

Juveniles: have a dark brown crown and neck, whitish chin, grey-brown fore neck and breast, and brownish-white belly blotched with darker brown and orange-brown. They have blackish flanks and the under tail-coverts are black-brown, the back has lighter feather edges, and grey-tinged scapulars and upper wing-coverts with dark edges. The bill is yellowish.

Size: body length = 45–55 cm, wing span = 80–90 cm, wing length (males) = 195–217 cm, (females) = 193–208 cm, weight (males) = 650–870 g, (females) = 565–640 g, bill length (males) = 30.5 mm, (females) = 29.2 mm.



Figure 11.2 Pygmy Cormorant nestlings. Photo courtesy of S Volponi.

11.1.2 Diet

Primarily fish, but data are sparse with other prey only occasionally recorded, including young water-voles, frog larvae, crustaceans (e.g. shrimps), aquatic invertebrates and leeches. Remains of vegetarian origin may also occur in diet. Normally feeds during daytime either singly or in pairs. It is less often seen in groups (during winter mostly). Average weight of fish needed per day is estimated to be 115 g.

The pellets of the Pygmy Cormorants (unlike those of Great Cormorants) appear to have a smaller but thicker mucus covering, containing very few remains from the fish eaten (otoliths in general). Empty pellets are not unusual. The pellets can be opaque white, yellow or brown coloured. As roosting sites are, in most cases, located over water, most pellets just fall into the water or become useless for analysis as any bones fall from the waterlogged mucus. Thus only those pellets that fall onto dry ground (or that become stuck

on trees branches) can generally be collected and used for further processing and investigation. Smaller fish species appear to be completely digested judging by their absence in pellets. Thus pellets from Pygmy Cormorants are not useful for estimating either fish species composition or the daily food intake of the birds — they merely give a very general picture of the prey taken.

11.1.3 Roosts

The roosting sites of Pygmy Cormorants are usually located on very inaccessible islands or flooded trees over the water. Unlike Great Cormorants, Pygmy Cormorants often arrive at roosts individually (especially at the beginning of a roost's occupation). Flocks of up to 120 or more birds arrive during the peak hours, but normally arriving groups number 2–40 individuals. Pygmy Cormorants do not wander around roosts, trying to see if it is safe enough, but land directly. However they do use the highest parts of neighbouring trees and bushes to check the roost sometimes. As dusk approaches, birds occupy the main roosting trees and bushes, especially their lowest branches (unlike Great Cormorants), where they concentrate at up to 6–8 birds per linear meter. Although foraging birds can be present at a roosting site throughout the day, the first birds usually arrive about 3 hours before dusk, and the peak arrival time is 60–90 min before dusk. The roost may be considered



Figure 11.3 Pellets of Pygmy Cormorants. Photo courtesy of I Nikolov.

occupied some 20–30 min before dusk (contrasting with Great Cormorants, where some birds arrive after it is dark).

Flocks of Pygmy Cormorant appear to have no special order. They are ‘chaotic’ and much more difficult to count than the Great Cormorant’s V-shaped flocks. Additional difficulty may be caused by the way the birds fly — sometimes Pygmy Cormorants make loops within the flock just before landing at the roost, thus disarranging the formation even more. This behaviour means that to count a returning flock as accurately as possible, it should be observed at least 200–300 m before reaching the roost site.

The best time for counting larger roosts is before dusk as birds/flocks arrive one by one. There are two main reasons for not counting Pygmy Cormorants in the morning: most of the birds take off at the same time (not in small groups) and accurate counting is not possible at all; on the other hand as the birds are highly concentrated on the tree branches (and many of them remain invisible in the dense group) it is also not possible to count them accurately while they are standing in the roost.

When counting bigger roosts of Pygmy Cormorants a few things should be considered. Counts generally require the presence of a second observer, as birds may arrive from any direction and if the roosting territory is big enough (and has many trees), lots of birds can be missed. Thus the two counters may be forced to count separately from the opposite sides of the roosting site with a preliminary stipulation about the method of counting. Again, depending on the location

of the roost, many birds may arrive individually at the same time from many directions and even if the whole roost could be overlooked by one person, it is not always possible to follow and count all the birds. Many birds approach the roosting site flying very low over the water (3–10 m) and if the background is dark (or the roosting site can not be overlooked from an observation point) they can be easily missed if only one person counts. Sometimes during the peak hours of roost occupation, all the birds take off for no apparent reason and fly over the roost whilst other birds continue to arrive at the same time — an impossible situation to handle for just one observer.

11.1.4 Breeding

Pygmy Cormorants produce one brood, the clutch size = 4–6 eggs (usually 3–7). Egg length = 40–52 x 28–33 mm and egg weight = 23 g. Incubation lasts 27–30 days.

Colonies are often polyspecific (mixed with herons, egrets, spoonbills, ibises or other cormorant species). Nests are located on trees or in dense reedbeds. While counting or ringing birds within colonies the fact that many other species may be present too (with different breeding periods and behaviour) must be considered carefully as such activities within the colony may cause significant and undue disturbance to the whole mixed colony.

11.2 European Shag (*Phalacrocorax aristotelis*)

The European Shag is found almost exclusively in salt water off rocky

shores and cliffs. It is smaller than the Great Cormorant and lacks that species’ white chin and thigh spot in the breeding period. During this time the European Shag has a pronounced head crest. The wing-beats of the European Shag are considerably faster than those of the Great Cormorant. The overall green gloss of the Shag’s plumage and its yellow bill base and gape separate it from the other European cormorant species. At longer distances it is sometimes difficult to distinguish European Shags and Great Cormorants but at all times the slimmer build, shorter neck, smaller head and faster wing-beats of the Shag help identification. There are two subspecies of European Shags in Europe: *P. a. aristotelis* (north and west) and *P. a. desmarestii* (Mediterranean and Black Sea).

11.2.1 Sex & age

Adults: The breeding plumage of the European Shag is mainly oily black glossed dark green, but the head and the neck are glossed dark blue-green. The mantle, scapulars and wing-coverts are purplish, latter feathers are bordered with velvet-black to give a scaled effect across the mantle and wings. The forward-curved crest is usually conspicuous during the breeding period. They have a black bill with a yellow base to the lower mandible and an orange-yellow gape. The eyes are bright green. The legs and the feet are black. The non-breeding plumage (moult starts June–August) is duller and browner without the crest, whilst the chin is white to brownish-white and the throat is brown.

Juveniles: The juvenile plumage is medium to dark brown above with



Figure 11.4 Adult European Shag (*P. a. aristotelis*).

Photo courtesy of R Bardgett.

inconspicuous green gloss. There is a scaly effect on the mantle and scapulars but pale tips to the wing-coverts and colouration is paler on the sides of the head. Plumage is generally paler brown below, with small but variable areas of brownish-white on the chin and in the centre of throat, on the breast and belly. The *P. desmarestii* race is wholly whitish to brownish-white below.

Adult shags are unmistakable and immatures differ from young Great Cormorants in their smaller size, slimmer build, and much more slender bill. Also, (except for *desmarestii*) there is much less white on the brown breast, though sometimes there is a white spot on the chin.

Size: body length = 65–80 cm (males on average larger), wing span

= 90–105 cm, wing length (males) = 261–278 mm, (females) = 251–269 mm, weight (males) = 1,930 g (breeding time), bill length (males) = 55.0 mm, (females) = 55.3 mm.

11.2.2 Diet

Chiefly and often entirely fish, most times caught under water and brought to the surface. Unlike the Great Cormorant, which (at sea) mainly hunts on bottom-living fish species, European Shags prefer species of the open like *Clupeidae* (Herring fishes) and *Gadidae* (Cod fishes). As with other cormorants, European Shags produce pellets which contain the undigested remains of their prey.

11.2.3 Roosts

Shags are less gregarious than Great Cormorants. They often

remain solitary in winter and when away from the nesting colony. Occasionally they flock at fish shoals but with minimal social interaction. This essentially marine species does not usually range far from the coast, preferring rocky coastlines, where they roost on stack rocks or cliffs. Large numbers may use the same rock, but some roost alone on narrow ledges.

11.2.4 Breeding

European Shags produce one brood, the clutch size = 1–6 eggs (usually 3), egg length = 52–72 x 35–41 mm, egg weight = 49 g, incubation lasts 30–31 days.

Shags usually breed in small, loose colonies, though sometimes densely. They defend only the nest-site territory.



Figure 11.5 Adult European Shag *P. a. aristotelis* taking flight – identifiable by greenish plumage, head crest, yellow base to lower mandible, and indication of fast (frequent) wing beats. Photo courtesy of Scott Jones.

12 APPENDIX TWO: NATIONAL AND INTERNATIONAL CORMORANT COUNTS, EXAMPLES OF DATA FORMS

Centrale Ornithologique Aves

(1) Belgium

| Recensements hivernaux 2008 - 2009 des dortoirs de Grand Cormoran | | |
|----------------------------------------------------------------------------------------------------------|---------------------------|--------------------------|
| Site (localité, lieu dit; si nouveau site, coordonnées Lambert ou autre localisation précise) : | | |
| Date : | Heures : de à | |
| Observateur (s) : | | |
| Météo locale (préciser si problème pour le dénombrement) : | | |
| Remarque concernant le dénombrement : | | |
| Autres espèces présentes en dortoir (Grande Aigrette, Héron cendré, etc.): | | |
| Nombre total (final) de Grands Cormorans : | | |
| Age-ratio : | | |
| Nombre d'adultes : | | |
| Nombre d'immatures : | | |
| Nombre d'indéterminés : | | |
| Origine ou départ de Cormorans pendant le dénombrement : | | |
| Nombre | Heure | Venant de / Partant vers |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| Observations d'oiseaux marqués : | | |
| | | |
| | | |

Besoin d'un complément d'info ? Jean-Yves Paquet, Rue du Vivier, 2, 5501 Awagne (0473 50 13 19)
jean-yves.paquet@aves.be



(2) France

Ministère de l'Ecologie et du Développement Durable
RECENSEMENT DES DORTOIRS DE GRANDS CORMORANS
HIVERNANTS
HIVER 2002-2003

Fiche à retourner remplie à :

Loïc Marion, coordinateur national
 MNHN-Université de Rennes
 Laboratoire d'Evolution des Systèmes
 Naturels & Modifiés, Campus Beaulieu
 35042 RENNES cedex
 tel. 02 23 23 61 44 fax 02 23 23 51 38

(IGN)

Organisme recenseur :**Nom du coordinateur départemental ou régional :****Nom de l'observateur :****adresse de l'observateur :**

| | |
|-----------------------------|---------------|
| Département : | N° |
| Commune : | Code postal : |
| Nom du dortoir, lieu-dit : | |
| Coordonnées géographiques | |
| Date du comptage : | |
| Heures du comptage : | |

| RECENSEMENT DU DORTOIR | Nombre d'oiseaux présents au dortoir au mois de : | | | | | |
|---------------------------------------------|---------------------------------------------------|----------|----------|----------------|---------|------|
| | Octobre | Novembre | Décembre | Janvier | Février | Mars |
| Recensement de 2000-01 (rappel) | | | | | | |
| Evolution intermédiaire (si connue) 2001-02 | | | | | | |
| Recensement de 2002-03 | | | | | | |

Biotope et supports du dortoir :

(4) European level — WI-Cormorant Research Group 2003 pan-European winter count.



Wetlands International - Cormorant Research Group

National coordinators please collect forms in your country and send national results and map indicating the location of roost sites to European coordinators (postal address see information leaflet):
 North+West EU: Loic Marion, Loic.Marion@univ-rennes1.fr
 Central EU: Rosemarie Parz-Gollner, parz@mail.boku.ac.at



**Pan European Cormorant Midwinter Census
 January 2003**

Part A - Affiliation and location

| | | |
|-----------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-----------------------------------|
| COUNTRY | name of province | Date of counting |
| Name of respondent / local counter | | counting time from - until |
| Location - name of roost site/ add also name of waterbody, river etc. | | |
| geographical coordinates of roost site / or nearest town, village.... | | |
| type of water body (please specify: marine coast, river, lake, pond...) | | |
| type of roost site (please specify: trees, bare ground, pole in the water, islands, platforms, artificial structures, others...) | | |
| local climatic conditions - (wind, ice-cover, rain-, snowfall, fog, good view....) | | |

Part B /1 - counting data

| time | number | activity of birds, remarks |
|----------------------------------------------------------------|--------|----------------------------------------------------------------------------------------|
| | | |
| | | |
| | | |
| | | |
| | | |
| Total (final) number of cormorants present: | | <i>use back side for further notices, additional counting results and observations</i> |
| Age-ratio | adult | juvenil / immature |
| number (N) | | |
| estimate (%) | | |
| accuracy of counting / data record - (100%, 75%, 50%, <50%...) | | |

Wetlands International - Cormorant Research Group

13 APPENDIX THREE: 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 meetings, but are not named individually here.

| | Name | Affiliation and country |
|----|-------------------------------------|-------------------------------------------------------------------------------------------------------|
| 1 | Mennobart van Eerden (WG1 Co-chair) | Institute for Inland Water Management and Waste Water Treatment (RIZA), Netherlands |
| 2 | Stef van Rijn (WG1 Co-chair) | Institute for Inland Water Management and Waste Water Treatment (RIZA), Netherlands |
| 3 | Stefano Volponi (WG1 Co-chair) | Instituto Nazionale Fauna Selvatica, Italy |
| 4 | Zeef Arad | Institute of Technology – Technion, Israel |
| 5 | Dariborka Barjaktarov | Natural History Museum, Belgrade, Serbia |
| 6 | Janis Baumanist | Institute of Biology, Latvia |
| 7 | Thomas Bregnballe | National Environment Research Institute, Denmark |
| 8 | Szymon Bzoma | Sea Fisheries Institute, Gdynia, Poland |
| 9 | Henri Engström | University of Uppsala, Sweden |
| 10 | Manfred Enstipp | Centre for Ecological and Physiological Energetics, Strasbourg, France |
| 11 | Marijan Govedic | Centre for Cartography of Fauna and Flora, Ljubljana, Slovenia |
| 12 | Reinhard Haunschmid | Federal Agency for Water Management, Institute for Water Ecology Fisheries and Lake Research, Austria |
| 13 | Mikael Kilpi | ARONIA Environment, Åbo Akademi University & Sydväst Polytech, Finland |
| 14 | Emmanuil Koutrakis | Fisheries Research Institute, Greece |
| 15 | Vilju Lillileht | Estonian Agricultural University, Tartu, Estonia |
| 16 | Svein-Håkon Lorentsen | Norwegian Institute for Nature Research (NINA), Norway |
| 17 | Loïc Marion | University of Rennes, France |
| 18 | Karlis Millers | Institute of Biology, Latvia |
| 19 | Ivailo Nikolov | BALKANI Wildlife Society, Sofia |
| 20 | Jean-Yves Paquet | Central Ornithologique Aves, Belgium |
| 21 | Josef Ridzon | Society for the Protection of Birds in Slovakia, Bratislava, Slovakia |
| 22 | Josef Trauttmansdorff | Otto Koenig Institute, Stockerau, Austria |
| 23 | Catarina Vinagre | University of Lisbon, Portugal |
| 24 | Ian Winfield | Centre for Ecology & Hydrology, Lancaster, UK |



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