3 COUNTING CORMORANTS

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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.

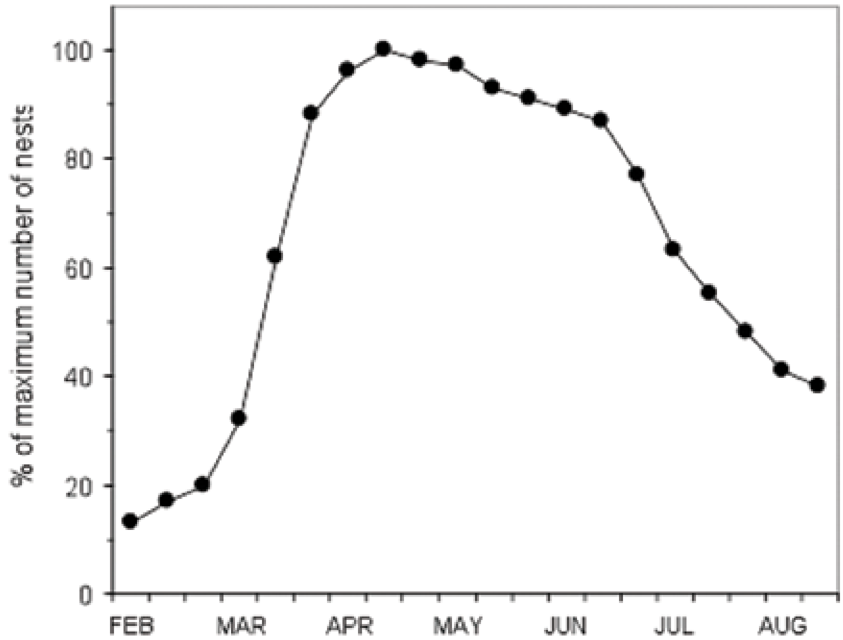

Figure 3.1 Seasonal change in Cormorant nest numbers given as the percentage of the maximum number of nests counted in each 10-day period in a section of the Vorsø colony in 1983.

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 *P. c. carbo*
Denmark[2]	25 April–10 May	Coastal as well as inland colonies
England[3]	12 April–17 May	Inland colonies of mixed *sinensis/carbo*
Wales[3]	10 May–7 June	Coastal colonies of *P. c. carbo*
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, Kopciewicz *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 Vorsø 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

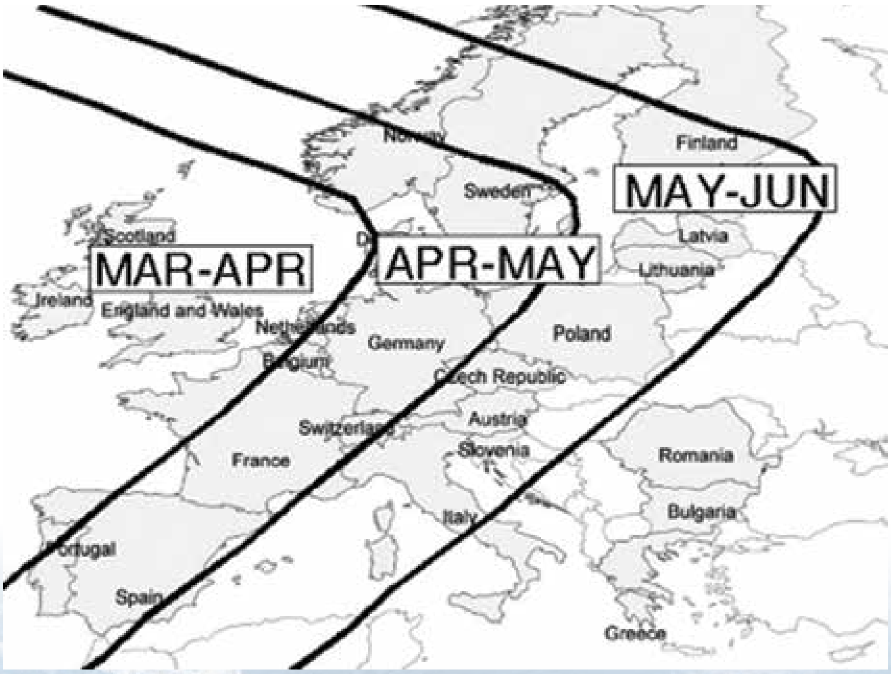

Figure 3.2 Sketch of the general time shift in breeding Cormorants from north to south and west to east across Europe.

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 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.

Figure 3.5 Tree colony in Lepelaarplassen in the IJsselmeer area, Netherlands.
Photo courtesy of Mervyn Roos.

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

- 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.

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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 night-time 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	▪ 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	▪ 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	▪ 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

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

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

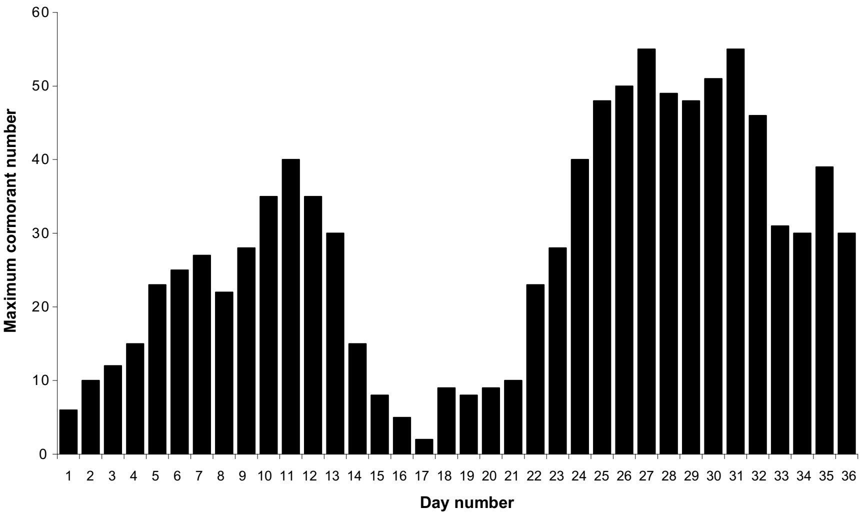

Figure 3.8 Hypothetical daily Cormorant counts (maximum number observed) at a foraging site. Birds were counted by a trained observer at a standard time of day and weather conditions remained similar throughout the 36 day counting period. Example A Table 3.3.

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

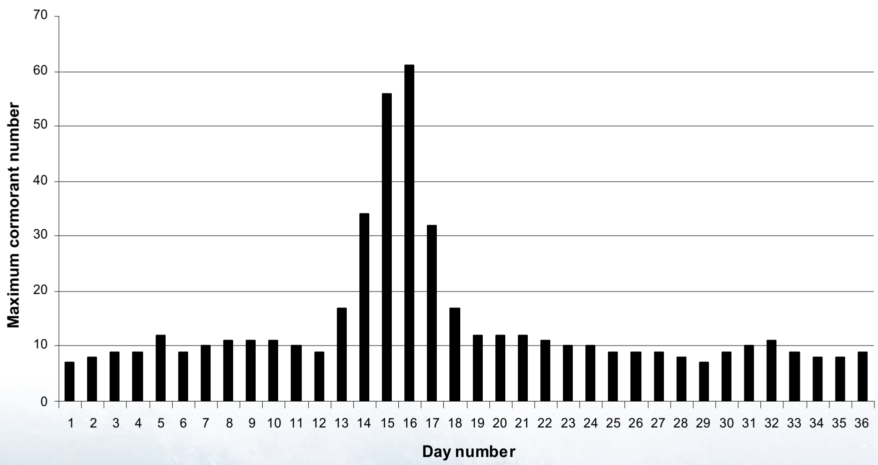

Figure 3.9 Hypothetical daily Cormorant counts (maximum number observed) at a foraging site. Birds were counted by a trained observer at a standard time of day and weather conditions remained similar throughout the 36 day counting period. Example B Table 3.3.

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

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

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, Kopciewicz *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 & Yorio 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 where 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.