International guidelines for monitoring breeding populations and levels of reproduction in the Eurasian Curlew *Numenius arquata*

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Please note the authors are happy to provide further advice and support on Eurasian Curlew monitoring projects, new and old.

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Copyright and suggested citation

Suggested citation: de Jong, A., Bocher, P., Brown, D., Franks, S., Gerritsen, G., Meyer, N. & Sviridova, T. (2021) International guidelines for monitoring breeding populations and levels of reproduction in the Eurasian Curlew *Numenius arquata*.

Summary

The Eurasian Curlew *Numenius arquata* is a species of global conservation concern. It is classified as globally Near Threatened on the IUCN Red List and several important breeding populations continue to decline. In 2015, an international conservation plan for the species was produced under the framework of the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA).

These guidelines have been produced to help support the implementation of the AEWA plan and seek to encourage, support and expand the monitoring of breeding populations of Eurasian Curlew across the breeding range. It has been written by a group of researchers from several countries, whom between them, have combined experience 'in the field' spanning several decades.

The introductory chapter covers a range of topics including survey design, monitoring programmes in general, the focal species, its breeding ecology and processing results. The second chapter covers methodologies for surveying population size, including point counts, area searches and territory mapping. The third and final chapter addresses population-level reproduction and describes methodologies based on nests (e.g. clutch size and hatching success) and post-hatching survival.

The guidelines also contain descriptions of field techniques and equipment to aid surveys and throughout the guidelines are a range of helpful pictures from active research and conservation projects from across the breeding range.

The ultimate goal of the guidelines is to improve the evidence base for assessing the conservation status of the species and the three recognised subspecies. For this, survey data from less well-studied parts of the breeding range, e.g. Eastern Europe including Russia, are in high demand.

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Preface

Scope and aims

In November 2015, at the 6th Session of the Meeting of the Parties to the African-Eurasian Migratory Waterbird Agreement (AEWA), an *International Single Species Action Plan (ISSAP) for the Conservation of the Eurasian Curlew* (Brown 2015) was adopted. The implementation of the ISSAP is now an ongoing process, internationally and nationally, and recent years have seen an expansion of conservation, research and monitoring projects.

Consequently, there is a growing need for high-quality monitoring data, effective management tools and in-depth research. In this document, we present guidelines for monitoring breeding populations and their reproduction. Many other aspects concerning the biology of Eurasian Curlew merit further study, such as migratory connectivity, population structure, genetics and basic autecological traits, particularly in a range-wide context. We hope other guidelines and complementary projects will deal with those aspects in the near future.

These guidelines were developed for the AEWA Eurasian Curlew International Working Group (ECIWG) within the framework of a workplan for the period 2018-2021. The workplan was agreed at a meeting in Aberlady, Scotland in 2018. Workplans seek to aid implementing ISSAPs by identifying discrete projects and areas of work to take forward.

The aim of these guidelines is to support new monitoring projects, particularly in countries and regions where limited monitoring of Eurasian Curlew (hereafter, "EC") populations has been undertaken to date. They also seek to harmonize and refine data collection from existing monitoring projects.

Ultimately, the goal of these guidelines is to assist efforts to move the EC towards a more favourable conservation status at national and international levels, through evidence-based conservation and management actions guided by results from high quality and comparative monitoring studies.

We intend to keep this a 'live' document and hope to improve it over time. If you have comments, questions or suggestions that could improve future versions of these guidelines, please let us know.

Reading instructions

The editorial team has tried to facilitate easy access to the methods and the background information by the use of extensive 3-level numbering of chapters. We suggest you start with reading through the List of Contents.

The guidelines contain three main chapters (Chapter 1-3). Each of these is introduced by a summary overview, which intends to guide you through the chapter's contents.

Chapter 1 provides information and advice for the planning of surveys (Chapter 1.1), about the focal species and its breeding habitat (Chapter 1.2) and on aspects of data handling and publishing of results (Chapter 1.3).

Chapters 2 and 3 describe survey methods for breeding populations and for reproduction, respectively. Each method description starts with a definition of the measurement unit (**what** is surveyed), followed by a set of aspects you may want to consider before applying the specific method.

Finally, the document contains a set of supportive texts in text boxes, a reference list (Chapter 5) and eight appendices. The appendices present general technical and methodological information that can be useful for EC surveys, and supplementary photo documentation of breeding habitats, nests and eggs.

1 Background

PLANNING

- Important questions before you start: What are your goals? What resources are available: time, funding, equipment, etc.? What is the time frame of the breeding season? What legal permissions are needed? Is a PR strategy appropriate to engage other parties involved?
- Choose the study area wise: presence of EC, accessibility, topography, etc.
- Consider a pilot study: Is the study design feasible and effective?
- Describe and save your data properly and, if possible, publish them.
- Be aware of your study's own impact (e.g. CO_2 emission).

KNOW "YOUR" BIRDS

- Identification: Male/female; juvenile/adult; similar species (e.g. Whimbrel)
- Good description of breeding habitats: varying types in open landscapes.
- Status of the bird: part of the breeding population, migrant or non-breeder?
- If part of the breeding population, describe pairs or territories. Be aware of misinterpretations.

NEST FINDING

- Learn nest-building behavior, egg-laying (4-6 days for a complete clutch of 4 eggs), incubation (28-30 days) incl. hatching phase (2-5 days).
- Start early in the season, minimize disturbance.
- Be aware of relays after the loss of first-clutches, but be careful with misinterpretations.

NEST MARKING

- Only if necessary, e.g. to avoid destruction from farming, with 1-2 markers as far away from the nest as possible.

NEST MONITORING

- As rarely as possible but as often as needed (depending on the goal of your study).
- Get familiar with signs that indicate the nest fate: predation, destruction, desertion, hatching.
- Predict hatching dates: minimize disturbance (from repeated visits) and ability to communicate dates with involved farmers.

CHICKS

- Important to (1) protect chicks from e.g. farming practices and (2) estimating the breeding success.
- Precocial chicks are very mobile and well camouflaged. Their movement can be monitored by monitoring the parents (learn to interpret the behavior of guarding parents).
- Try to avoid too many disturbances (danger of stepping on chicks and/or hypothermia).
- Chicks can be marked (e.g. rings, radio tags) to gain exact data of their movement, but these methods are very interfering and labor-intense.

DATA & STATISTICS

- Document your study thoroughly: what you did and what you found.
- Be aware of bias: search-, detection-, behavior-, status-, observer and effort-bias.
- Observation effort should be harmonized (e.g. observation bouts or fixed durations).
- Be aware of unobserved (invisible) birds. Try to minimize this problem by choosing the observation times smart.
- Keep data structure easy, make your data available and choose a good computer program for advanced analysis.
- Repeating your observations (e.g. successive years) is advisable, but requires good planning and/or expert advice to avoid false conclusions. From repeated observations, trend analysis can be developed with matching models that take errors into account.
- More is not always better. Choose a good balance between sample size (number of repetitions), effort (cost and labor) and output (a semi-perfect, well documented, accessible dataset might be of more importance than a dataset that never gets published because it is not yet "perfect").

1.1 Planning pays

Whether you are an interested amateur or a professional researcher, effort spent on the planning and preparation of your survey will be time well spent. This also includes 'learning to know' your birds well before the onset of your study.

1.1.1 Clear and realistic goals

Surprisingly often, people put a tremendous amount of effort into projects with very unclear goals! Spontaneous projects may be fun and exciting but often, they produce disappointing and unreliable results. When you carefully choose your goals, and are prepared to revise them if needed, it will be much easier to evaluate, interpret and communicate your results.

1.1.2 Assess your resources and conditions first

Given the goals, you should make a realistic assessment of the resources available for your project, both short-term and long-term. How much time, funding, equipment, etc. is available? Adjust your goals if your resources are insufficient or seek more resource. During this inventory process, you should also ask yourself a reasonable number of "What if …?" questions: e.g. What if participant X is no longer available? or What if funding agency Y stops supporting us? Even very down-to-earth questions can be highly relevant, e.g. What if road Z is no longer accessible by car? You will never be able to foresee everything, but you can probably avoid a wide range of problems by thinking ahead.

1.1.3 Timing and effort

For efficient timing of breeding population surveys, adequate knowledge of the phenology of the breeding season is essential, e.g. when adults return in spring, when eggs are usually laid and hatch, etc. This knowledge needs to include information about the average **and** the variation in timing of the breeding cycle. Additional knowledge about the causes of variation (e.g. weather) is desirable. Based on this information, you can continuously adjust your survey-plan if needed. Some of the timeframes can be narrow (e.g. the egg-laying phase) with significantly different survey efficiencies before, during and/or after.

The efficiency and the quality of your monitoring project also depends on the weather conditions during fieldwork. Try to avoid conditions that make the birds difficult to observe, e.g. fog, precipitation and strong winds.

1.1.4 Choice and description of the study area

In many cases, the study area is given *a priori*, e.g. by request of a nature reserve manager or your personal ornithological home range. If you can choose the study area more freely, you might consider a scientifically robust sampling procedure. This would enhance the chances for your results to be relevant for other areas through extrapolation and generalisation. In case you are unfamiliar with scientific study design, ask an expert. From a logistical point of view, factors like accessibility, human disturbance, availability of good maps and travel distances/times are also important considerations for study area choice. Additional information (e.g. vegetation maps, historic data or records of management) can be useful for the interpretation of your survey results and thus, a valid reason to choose an area for which this information is available. It is also wise to complement the existing habitat descriptions with up-to-date information over the course of your project, e.g. on land-use and crops. Photos and video footage can be helpful.

The topography and vegetation cover of the study area has an important impact on various aspects of the study design. If the landscape is not completely flat, ridges, depressions and back-slopes, and tall grassy or heath vegetation will have a large impact on visibility, and thus, detection rates. If full coverage is vital for the study design, the level of effort will rise with topographic complexity.

1.1.5 Permissions, ethics and PR

Your study must of course conform to legal, ethical and societal norms and rules. These vary between countries and over time. Make sure you know which rules apply! The penalty for breaking the rules can be legal fines, loss of financial support, reputational damage, unpublishable data or you may risk undermining conservation efforts (i.e. by alienating land managers).

Ethical rules for research using animals are increasingly important. Most countries have explicit rules for this, usually as part of their animal welfare legislation. Within the EU, individual countries may have special rules within the overarching EU framework (EU 2010). A central concept in animal welfare research is The Principles of the 3Rs (Russell & Burch 1959, de Jong 2019). The 3Rs stand for Replace, Reduce and Refine. A growing number of scientific journals have animal research ethics requirements for manuscripts. In case you cannot prove your study was in accordance with the relevant legal framework, your manuscript may be rejected.

Consideration also needs to be given to trade-offs between observation and disturbance, such that monitoring activities with the potential for causing significant negative impacts through disturbance are only performed if such activities are justifiable in the context of the study.

Even when your work follows all the formal rules, you may still get into conflict with members of your local society, e.g. with birdwatchers and nature-photographers who do not like markers on birds (Fig. 1). A public relations (PR) strategy will help to avoid and mitigate potential conflicts. Effort spent on communicating with and generating goodwill amongst local communities and stakeholders can be beneficial for your project, for example through offers of help, support or even funding. It can also help communicate issues facing local EC populations, and gather support for conservation action.

Figure 1. Even when the benefits of marking birds are obvious for your project, other people may find it offensive or challenge it. Photo: Harry Ewing.

1.1.6 Pilot study – change of method or site

A pilot study is a test version of the study you have in mind, usually at a limited scale and of limited duration. The idea is to test whether or not the study design is feasible and effective. If not, you can change it without losing much time, resources and data. If the original plan worked fine, you can just continue and scale up.

A key issue is that a change of method or site usually means that the data sets from before and after the change are incompatible. That is why you should avoid methodological changes during a full-scale survey. If changes are unavoidable, make sure to document them well. You can even run both methods in parallel for some time to see how the results relate to each other.

1.1.7 Documentation and publication

To sustainably help endangered species, it is crucial to describe your data properly, save it in an accessible and understandable way and, ideally, publish your findings.

Regardless of your storage medium of choice (paper, computer memory, tape, etc.), all the information needs to be properly described by "metadata". Metadata describes everything that is not obvious, e.g. abbreviations, shorthand column names and any kind of codes. If you think you have been overly explicit, describe things even more explicitly! Make sure the metadata remain connected with the data itself, even copies of the data. You should put a lot of thinking and effort into this, because the one without the other is virtually useless.

The absolute minimum rule for any documentation is that it includes a full description of *Where*, *When* and by *Whom* together with the *What*, i.e. a documentation of three observed ECs should come with information on where, when and by whom these birds were observed. Stick to standard units (m, s, etc.) and clarify time zoning (including summer vs winter times) and coordinate systems. In addition to written documentation, photos are often very useful, especially when your camera/smartphone adds a time-stamp and coordinates to them. Video and sound recordings can be helpful, but necessary post-processing may be time-consuming.

Redundancy (repeated information) is often considered a curse, but in scientific documentation, it can be a lifesaver. For example, the location of a nest marked on a map **and** written by its coordinates in your notebook will still be available when the map or your notebook gets lost. Saving field data on electronic devices alone is risky. Although hardware gets better and better, regular back-ups and/or internet downloads are a necessary insurance. Losing data hurts!

After the original documentation, you need to store your data media in a proper way. How to do this is beyond the scope of these guidelines. The key point is that your data could prove highly valuable many years into the future and to people in a completely different setting.

To make your data and results useful for others, you should make them accessible. This can be done in the form of publications, be it a simple report or an advanced scientific article. The "Golden Rule" is: If you cannot produce an advanced manuscript, make a simpler one. The correctness of the content is paramount, and so is transparency. You also need to consider which outlet to choose. Peer-reviewed scientific journals are traditionally preferred, but nowadays, you can choose from a wide range of alternative outlets for complete manuscripts, preprints, summaries and datasets (e.g. bioRxive.org, see also Mills et al. 2015).

1.1.8 Environmental issues

Your survey will probably have an impact on the environment, locally and globally. A full discussion of possible impacts and ways to mitigate and/or compensate for them is beyond the scope of these guidelines. The long-term goal of the iSSAP is to "restore the favourable conservation status of EC as demonstrated by its assessment as Least Concern against IUCN Red List criteria by 2025". This status is affected by a range of environmental factors, including the ones your survey has an impact on (e.g. disturbance, CO_2 emission from cars). Raised awareness can lead to informed decisions and reduced negative impacts.

1.2 The Eurasian Curlew and its breeding habitat

Throughout these guidelines, we will assume you know your birds well, preferably ***before*** *you start a major study. The outcomes and the cost-efficiency of your survey will be significantly better when you know what is going on in EC-world! In this chapter, we will serve you some pieces of knowledge that we hope can be helpful.*

1.2.1 Identification issues on breeding grounds

Males vs females

Females are generally bigger and have bills that are straight near the base and then curved. By these two features, many individuals can be sexed (especially when birds of both sexes occur close to each other), but there is significant overlap. Wise observers will refrain from sexing these intermediate cases. A broad overlap also exists in behaviour. Both sexes defend their territory, incubate eggs, help rear broods, and perform display flights, but females seldom "sing" (the repeated rapid "curloui" call). A characteristic female call is a long, unwavering falling whistle voiced from the ground. Also of note is that females often depart at some point during the chick-rearing period, with indications of females staying longer in the SW parts of the breeding range.

Juveniles vs adults

Towards the end of the breeding season, juveniles can still be distinguished from adults by their shorter bills, tuffs of down, fresh plumage without signs of moult and "clumsy" flight (Fig. 2 and 3).

Figure 2. Juvenile EC shortly after it became capable of flight.
Photo: Harry Ewing.

Figure 3. Juvenile EC just before they can really fly. Photo: Gerrit Gerritsen.

Whimbrel vs EC

In large parts of the EC breeding range, Whimbrel (*Numenius phaeopus*) can stop over during migration (mainly pre-breeding migration). Under good conditions, the species are easy to tell apart (e.g. by size, bill shape, head strikes and vocalization), but under poor conditions, the following additional features can help. Whimbrel look darker and more uniformly coloured than EC, and when not resting, Whimbrel move "nervously" (quick and zigzagging) during surface-feeding and often lift for short flights, seemingly unprovoked.

1.2.2 Breeding habitat

Throughout its range, EC breed in a wide variety of habitats, from coastal salt marshes to flood plains to mires to moors to intensively-managed farmland (Fig. 4). These are all "open" habitats, but this does not mean that EC completely avoid shrub land, sparse tree stands, forest edges and settlements. EC neither spend much time nor lay their nests in forests, industrial sites and truly urban surroundings, and do not breed above the tree line, neither in Alpine nor in Arctic environments (Shimmings and Heggøy 2019). Obviously, you will not find EC nests on hard surfaces of roads, airstrips or buildings, but nests can be placed surprisingly close to such features, e.g. on the verges of roads or airfields (Fig. 5). Unlike Whimbrel, EC do not seem to breed on boreal clearings (nowadays after logging, but originally after wind-throw or wildfires).

Considering the wide variety of EC breeding habitats, publications of survey results benefit greatly from an adequate description of the habitat in the study area. Maps and photos are particularly informative. Our current knowledge about EC populations and their reproduction is strongly biased towards agricultural habitats and thus, surveys of non-agricultural habitats are in high demand.

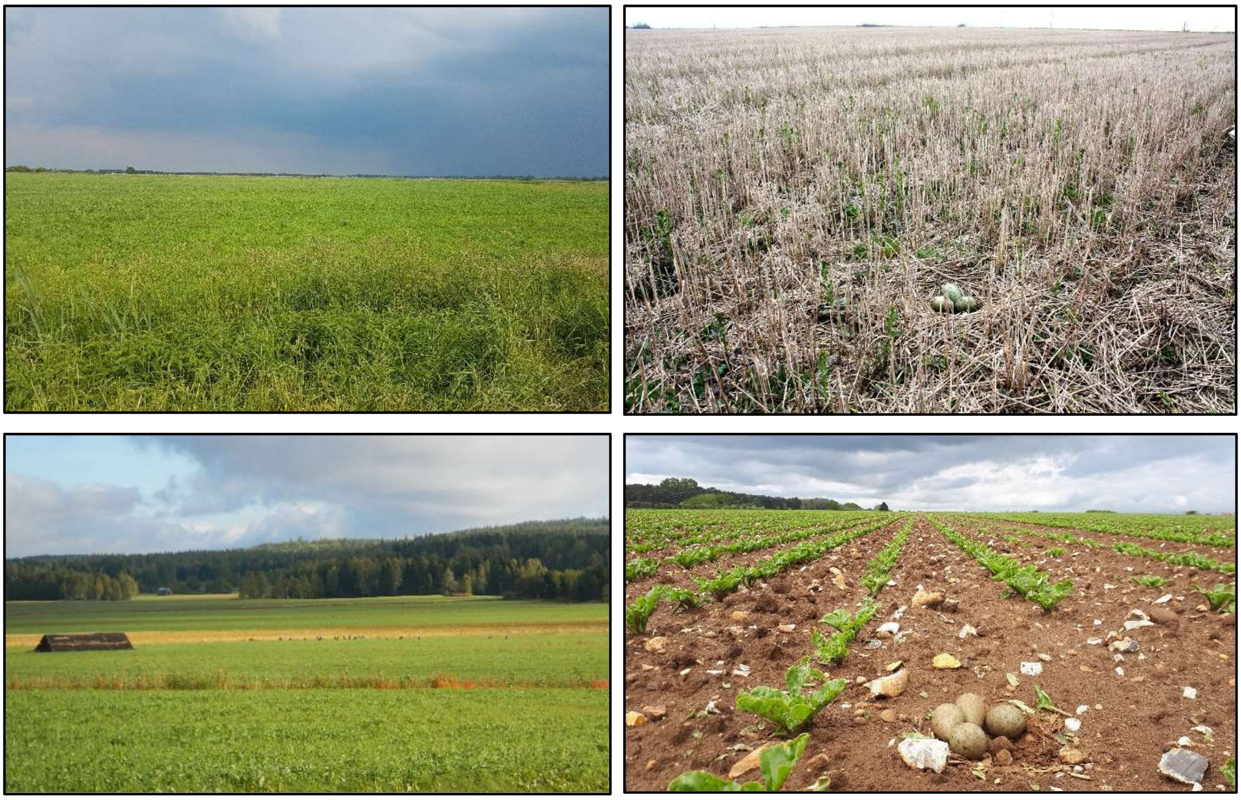

Figure 4. Various types of EC breeding habitat. Clockwise: Lowland wet grassland, cereal stubble, mixed farmland in stream valley and single-sown crop on arable land. Photos: Natalie Meyer (upper left), Tatiana Sviridova (upper right), Adriaan de Jong (lower left) and Harry Ewing (lower right).

Figure 5. EC nest in vegetation reclaiming an abandoned airstrip.
Photo: Harry Ewing.

1.2.3 Breeding bird or not?

Of the EC you will observe during your survey, not all may necessarily be part of the breeding population. In this context, we define the breeding population as "All the individual ECs within a given area that participate or try to participate in reproduction during the current breeding season." Consequently, "helpers" would be included in the breeding population, but individuals that come to the breeding area without taking part in the overall reproductive effort (e.g. migrants) are not.

Migrants
The risk of encountering migrants during your survey depends on the location and the habitat of your study area. The bad news is that both pre- and post-breeding migrants from the entire part of the EC breeding range north and east of your study area could potentially interfere with your survey. The good news is that, generally speaking, migrants tend to behave differently and choose different habitats compared with local breeders. As a rule-of-thumb: migrants often occur in flocks, move farther when disturbed, prefer wet habitats, seldom sing or make display flights and spend more time feeding and resting than on social interactions. Unfortunately, these differences are not always clear-cut and particularly individuals that are approaching their breeding area are likely to behave like breeders during stopovers. Good knowledge of your "own" local birds helps to make qualified judgements.

Non-breeders
The EC is a long-lived species and most individuals will not enter the reproductive phase before they are in their 3rd to 4th calendar year (= c. 2-3 years old), with likely variations for sex, population density, habitat, sub-population, etc. This means that a significant proportion of the **overall** population during the breeding period consists of non-breeding "adolescents". Most of these adolescents stay in wintering or favourable staging areas over the breeding season, but some may show up in your study area as "prospectors". Their numbers probably depend on the location and habitat of your area. Unfortunately, there are no certain ways to distinguish un-marked prospectors from truly breeding birds. This means there may be a risk of over-estimating the true breeding population.

Some reproductively active individuals are temporarily idle due to delayed onset of nesting or early clutch-loss. These individuals belong to the breeding population, but they lack the connection to a nest and maybe even a territory, and consequently, their behaviour may differ from adults with nests or chicks (Chapter 1.2.4 for further details).

The presence of seemingly 'lonely' birds in marginal habitats or outside the expected breeding range can also cause interpretation problems. Was the partner present, but not detected? Was the bird a relic from a previously established population or the founder of a new one? Here, historic data can be helpful, and we advise you to consult the literature and the local community.

1.2.4 Pairs and territories

The concept of "breeding pair"

While EC largely form a monogamous pair for a breeding attempt, and often for the entire season, you should recognize the possibility of rarer reproductive behaviours such as polygamy, polygyny, single parents, intraspecific nest-parasitism and atypical behaviours in display and territory defence. Failing to do so may lead to misinterpretations of observations and imprecise or even faulty survey results.

The concept of territory[1]

Founded in studies of passerines, the concept of a fixed breeding territory established and defended by the male is deeply rooted among birdwatchers and ornithologists. For EC, things are a bit more complicated. Both males and females show territorial behaviours, but in slightly different ways and intensities. Territorial behaviour also changes over time, with an intensive period between arrival at the breeding grounds and clutch completion, and then a gradual decline during incubation and chick-rearing. In some areas (probably sites rich in food), adults and chicks seldom leave their breeding territory. In other areas, adults regularly move outside their breeding territory to feed, sometimes several km away. Even families with chicks can move away from the original breeding territory to find better feeding grounds. These movements blur or even erode the concept of a well-defined, fixed territory. Additionally, observational evidence suggests that the individuals in certain EC communities apply a sloppy version of territoriality and mix rather freely in "soft" territories. Under such conditions, the territory seems to be reduced to a small area defended for mate-guarding, mating and nesting. This area will also be defended against foreign females planning to lay their eggs in the territory-owners' nest (intra-specific nest parasitism), mainly by the female.

Territory structure may also become diffused when prospectors and idle breeders are present (c.f. Chapter 1.2.3). These individuals may or may not be tolerated in and between the territories of others, and they are likely to display semi- or quasi-territorial behaviours.

To sum up, while in some areas the patterns of territories and their inhabitants are easy to distinguish, in other areas the situation can be messy. This has a large impact on the feasibility of several survey methods, in particular territory mapping (Chapter 2.2.3). Until you are truly familiar with your study population: be careful in interpreting your observations, because some things may be different from what you expected.

[1] In this context, we differentiate between "territory" and "home range". A territory holds valuable resources and is defended against conspecifics by the individual or the pair. A home range is the area "lassoed in" by the points in the landscape where the individual (or the pair) has been. Some parts of this area are likely to be territories (breeding and/or feeding) and are defended, but in other parts, conspecifics may be tolerated or ignored.

1.2.5. Nest building, egg-laying, incubation and hatching

Nest sites are chosen and nest-scrapes "built" within a matter of hours, often multiple times by the same pair during a single breeding season. The final nest is usually lined with grass or straw by the female during the egg-laying phase, but some nests are completely barren. Some of the lining can also be used to cover the eggs before the onset of incubation (making nests with incomplete clutches harder to find). This nest material is only taken from the close vicinity of the nest; EC do not carry in nest material from afar.

Eggs are laid with one or two day's interval. The median ("normal") clutch size is four eggs, but complete clutches of 1-3 eggs occur, especially among replacement clutches. Clutches of five or even more eggs are rare and may involve a case of "egg-dumping" by one or more other females. Eggs with strikingly different colouration or shape may thus be the result of intra-specific nest parasitism (i.e. eggs laid by another female than the "owner" of the nest, Fig. 6, Appendix 8).

Eggs can be "quasi-incubated" before real incubation starts, mainly during nights and cold spells. During quasi-incubation, the parent sits lightly on the nest without opening the incubation patch. Full incubation may start just before clutch completion. EC eggs take 28-30 days to hatch.

The eggs in a clutch hatch semi-synchronized, i.e. theoretically at the same time, but in reality with intervals of several hours up to two days (Fig.7). Embryonic vocalization (i.e. sounds made by the embryo before hatching) may contribute to hatching synchronization. Hatching is a complex process that can take up to three days from the appearance of the first cracks to the complete emergence of the chick (Fig. 8).

After hatching, chicks start leaving the nest within hours and the brood permanently deserts the nest shortly after the last egg has hatched. Chicks may stay in the nest for up to a few days if weather conditions are bad. You can tell the age of very young chicks by wet down (first few hours, Fig. 9) and the egg-tooth (first one or two days, Fig. 10).

After hatching, parents usually leave most of the eggshells in or very close to the nest. Eggs usually open in two parts, the rounded bottom plus part of one side and the pointed tip with most of the sides. The pointed part is the largest part and has the shape of a small boat when left undisturbed (Fig. 9 & 11). The membranes are initially attached to the shells, but gradually detach from the rigid parts during repeated dry-wet cycles (Fig. 12).

EC can produce replacement clutches, when the first clutch is lost relatively early. It may not always be correct to judge late clutches as replacement clutches. Some individuals may simply need more time to get ready for egg-laying than the majority (this may relate to age, experience and status). Usually, replacement clutches are laid within 1-2 weeks after the initial egg-laying period, but occasionally some occur up to a full month later. Replacement clutches often have less than four eggs. The adults sometimes abandon very late (replacement) clutches just before or even during hatching. Tertiary replacement clutches are very rare and only when clutch loss occurred very early in incubation and in parts of the range where the breeding season starts relatively early (mainly in the southern and western parts of the range).

Figure 6. Example of an EC nest with aberrant coloured egg in an unusual large clutch, indicative of intra-specific nest parasitism. Photo: Adriaan de Jong.

Figure 7. Hatching is semi-synchronized within the clutch, and often stretches over a few days. Photo: Adriaan de Jong.

Figure 8. Examples of nests with eggs in various early stages of hatching.
Photos: Adriaan de Jong.

Figure 9. Chick shortly after hatching, with down still wet and tufted. Behind the chick are the large eggshell fragments typical for hatched eggs. Photo: Adriaan de Jong.

Figure 10. Newly hatched chicks after their down has dried, but the egg-tooth hasn't fallen off, yet. Photo: Harry Ewing.

Figure 11. Egg-tooth on the tip of the bill of newly hatched chick. The egg-tooth falls off within one or two days. Large eggshell fragments are also visible. Photo: Natalie Meyer.

Figure 12. Large eggshell fragments after successful hatching and several days of weather exposure. Fragments start to fall off from the membranes. Photo: Adriaan de Jong.

1.2.6 Finding nests

Finding nests is difficult and time-consuming, but doable. Nest can be found by carefully scanning for incubating parents from a distance, by observing behaviour and movements, by flushing birds from their nest or by following birds returning to their nest after disturbances (Fig 13). The efficiency of all these methods varies over the season and between landscapes. Thermal cameras (hand-held or carried by drones) can also be used to find nests. If you have access to these types of support, we assume you know to use it wisely. Recent studies have used drones to find and monitor EC nests. The results are promising but preliminary. Definite results and recommendations will be presented in future versions of these guidelines.

In most cases, finding **all** the nests in a given area is virtually impossible and **detection-bias** is likely to occur, e.g. nests on moors, in stubble or among tussocks are much harder to find than nests on smooth, short grasslands. If detectability correlates with measurements of reproductive success (which is likely!), this detection-bias affects the outcome of your survey (c.f. Box 1 on page 33).

In addition to detection-bias, searching intensively for nests in certain (e.g. easily accessible) places but less intense or not-at-all in other (e.g. "unlikely") places will cause **search-bias** (Chapter 1.3.2 and Box 1). The quality of your survey will increase significantly if you carefully document where you searched for nests and how much effort (time or mileage) you put into your nest search.

For most nest studies, early detection is preferred. Luckily, in many environments, vegetation is short early in the breeding season and thus, incubating EC are easier to see than later. Overemphasizing early searches may lead to the under-representation of second (or tertial) nest attempts, though. The "best" strategy for **your** survey depends on your objectives, the landscape and the welfare of the birds (c.f. Chapter 1.1.5).

Figure 13. Some incubating individual sit very tight on their nest. Photo: Adriaan de Jong.

1.2.7. Marking of nests

There is a widespread view that nest markers attract predators and increase egg predation. This view is not supported by scientific evidence, though (e.g. Hannon et al 1993, Whelan et al 1994, Bêty & Gauthier 2001, Zámečník et al 2018). Nevertheless, we suggest you only use markers when necessary. A single, inconspicuous object (e.g. a natural branch/stick or a stone) at a fixed distance (e.g. two metres) and in a specific direction (e.g. before the nest along the line of approach) is sufficient[2]. Make sure the marker is tall enough to be visible even when the vegetation has grown taller. GPS-coordinates are helpful, but come with accuracy issues (typically 10 m) and coordinates alone are often not enough to find the nest after some time. Note also, that markers may be damaged/destroyed/dislodged by farming operations (e.g. ploughing or mowing) or by livestock, but, under those conditions, the nest and the eggs usually failed, too.

Markers for making farmers aware of nests probably need to be much more conspicuous. Here, multiple poles with flags may be necessary, despite a possible trade-off between nest protection from farming activities and predation risk (Fig. 14).

Figure 14. Markers help farmers to avoid nests during agricultural operations.
Photo: Natalie Meyer.

[2] There is no need to use two sticks if you make the direction towards the nest explicit, e.g. in "line with the direction of approach" or "to the north of the nest". Explicitly visible nest markers can be used for other purposes, though, e.g. to alert farmers.

1.2.8 The fate of nests and eggs

Most EC nest studies have shown high levels (> 50%) of losses during the egg phase**.** Predation, destruction by farming activities and, in pastures, trampling by livestock are important causes of egg loss. Usually, all the eggs in the nest disappear or are destroyed (Fig. 15).

Figure 15. A nest without a trace of egg-remains after predation, probably by a larger mammal. A common sight in EC nest studies.
Photo: Adriaan de Jong.

Potentially harmful farming activities are ploughing, harrowing, seeding, rolling, cutting, burning and fertiliser applications (Fig. 14 & 16). Obviously, the tires of tractors and other "things on wheels" (including ATVs and motorbikes!) are also a threat to nests and eggs, but these affect only a fraction of the surface of a field. The intensity and timing of farming activities vary between regions, and so therefore can their impact on EC reproduction.

Figure 16. Nest detected, marked and saved by a EC-friendly farmer during harrowing (when the nest was detected) and sowing barley in spring. The nest was depredated a few days after the photo was taken. The predator may have been guided by the deviant, clearly visible features around the nest. Although this is a likely outcome for nests salvaged by farmers, at least this nest had a chance of survival. Had the farmed just ignored it, the nest would have been instantly destroyed with 100% certainty. Photo: Adriaan de Jong.

The list of confirmed avian and mammalian predators is long, but Red Fox, Badger, Raccoon Dog, Wild Boar, Raven, Hooded/Carrion Crow and Common Crane dominate the top of this list. None of these species are obligate egg-consumers, though - they are opportunistic egg predators during the breeding season, and their population densities are mainly driven by other factors than wader eggs. Overall, egg predation is a complex phenomenon and requires careful study to become fully understood.

Predators usually take all the eggs from the nest and partial predation is rare (but see Fig. 17). It is not always easy to determine which predator has caused egg- or nest-failure. When all eggs have disappeared without a trace in a short period of time (Fig. 15), the predator was probably a large bird (Carrion/Hooded Crow, Raven, Common Crane or a large gull) or, more likely, a medium- to large-sized mammal (Red Fox, Badger, Raccoon Dog, Feral Dog, etc.). Livestock will also eat eggs (Fig. 18).

When eggshell fragments are present in or close to the nest, these provide clues to the fate of the eggs. Remains after hatched eggs are large and characteristically shaped (Fig. 9 & 11), even when most of the outer structures have fallen off and only the membranes are intact (Fig. 12). The size and the edges of eggshell fragments from predated eggs can be checked for bite marks (mammals) or signs of penetration by sharp bill-tips (birds) (Fig. 19 – 21). Sticky smears of egg content present in predated nest show that the eggs were eaten on the spot by a predator that neither moved the egg nor swallowed them whole (Fig. 17). Quite often, the nest bowl has been partially “dug-up” (probably more often by mammals than by birds). Generally speaking, nests without characteristic remains after hatched eggs can be classified as predated. Who the predator was will often remain uncertain.

Figure 17: Partially predated nest with egg content in the nest cup. Probably predated by a bird. Photo: Natalie Meyer.

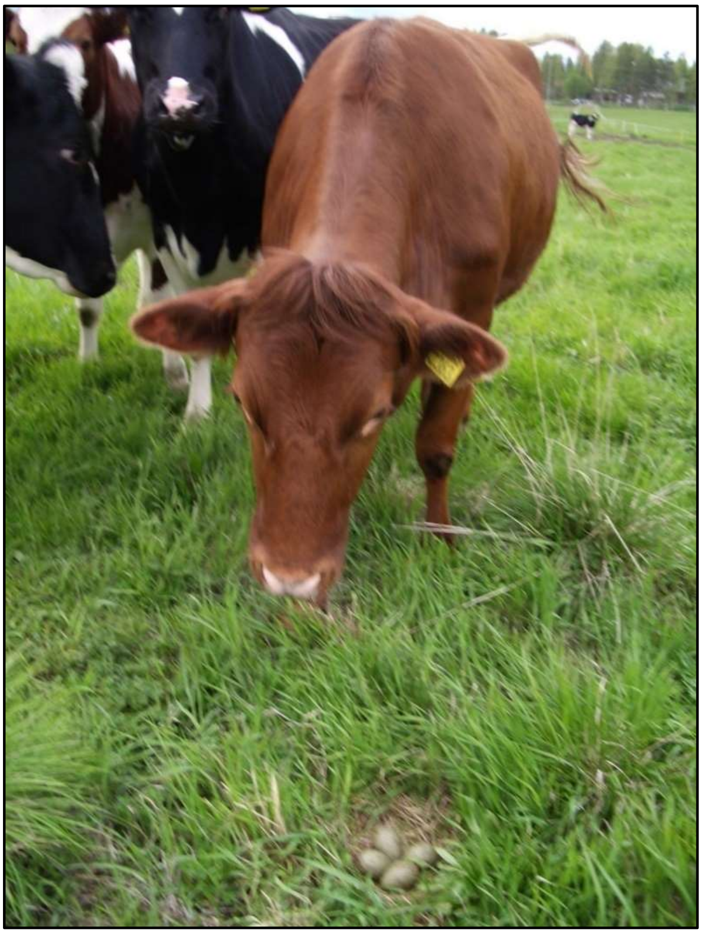

Figure 18. Livestock and EC nests do not always combine well. This picture was taken ("on the fly") seconds before the cow ate all the eggs. This herd of cows had just been introduced on the field. Photo: Adriaan de Jong.

Figure 19. Depredated nest with eggshell fragments and uprooted lining in the nest cup. The predator was probably a bird. Photo: Adriaan de Jong.

Figure 20. Predated eggs have been removed from the nest (encircled) prior to consumption. Photo: Tatiana Sviridova.

Figure 21. Nest predated by a bird. One egg is broken, but the others have only been punctured. Photos: Tatiana Sviridova.

Nest visits by researchers (or others), markers and monitoring equipment are often claimed to significantly increase predation risk and thus, influence the outcome of nest studies. Although these claims are not unambiguously supported by the literature, any unnecessary disturbances should be avoided. Our advice is: If nest visits, markers and/or monitoring equipment are important for your carefully planned study, go ahead. If not, avoid them. (c.f. Chapter 1.3.7).

In most published studies to date, the proportion of unhatched eggs has been very small, but from some regions, larger proportions have been reported (Fig. 22). If it is legally acceptable to do so and you have any necessary consents/ licences, we strongly recommend that unhatched eggs are collected and properly conserved for biological and chemical examination.

If all eggs in a nest failed to hatch (sometimes during the hatching process itself), the parents probably abandoned the nest. These cases are worth documenting properly. In general, nest abandonment (nest desertion) is a rare phenomenon, though.

Figure 22. Unhatched eggs are usually uncommon, but regional variation exists.
Photo: Adriaan de Jong.

Occasionally, an egg can be found just outside the nest bowl. It is unclear whether this is because the adult(s) lack a strong “egg retrieval behaviour” or they actively displaced the undesired egg from the nest as part of their anti-nest-parasitism behaviour (i.e. against eggs laid in the nest by other females). Similar to unhatched eggs inside the nest, these eggs can be collected for diagnostic studies after the nest has been deserted.

Chicks leave the nest shortly after hatching, usually within hours but sometimes after one or a few days, especially under adverse weather conditions (see also Chapter 1.3.5). Families do not return to the nest after they left it. Likewise, adults soon abandon completely predated nests. From all this, one can conclude that the measurements of nest success and hatching success are highly correlated.

You may want to mark the eggs for tracking the fate of individual eggs. Use a distinctive, yet inconspicuous coloured permanent marker pen. Put the marks near the sharp end of the egg, because the blunt end will easily become lost (= fragmented) during hatching.

1.2.9 Clutch size, incubation status and hatching dates

From observation alone, it is often difficult to determine the date of clutch completion and the onset/progress of incubation, or to predict hatching date.

In case the nest is found before the clutch is complete, only camera surveillance can replace repeated nest visits (egg-laying behaviour is diagnostic). Sequences of images or video footage are also helpful for clarifying the onset of incubation (but see Chapter 1.2.5). Cameras come in a wide variety of technical specifications, some at a significant cost. Make sure performance and durability match the objectives of your survey, e.g. in terms of how often batteries and memory cards need attendance (c.f. Appendix 5).

Under favourable circumstances (e.g. chilly mornings), a gentle touch on the eggs can reveal whether they were incubated (warm eggs) or not (cold eggs). On sunny days, sun-heated non-incubated eggs cannot be reliably distinguished from incubated eggs (both warm) and eggs are often brooded (but not incubated) by a parent during cold spells prior to the onset of true incubation. Consequently, this method should be used with caution.

With a van Paassen apparatus (Appendix 2), you can estimate the age of eggs thus allowing you can estimate laying, clutch completion and hatching dates. These estimates of hatching dates have an accuracy of 3-4 days. The van Paassen method builds on weight loss during incubation while the volume of the egg remains unchanged. The same phenomenon can be used to estimate the age of the egg from its weight and calculated volume (Appendix 3). The volume is calculated from lengths and width measurements, and the weight/volume ratio compared with a table. The accuracy of this “calliper-method” is also in the range of 3-4 days. Both methods work well with “normally” shaped eggs, but the estimates have larger errors for unusually shaped eggs, e.g. exceptionally long or bulky eggs (Appendix 7).

Incubation can be monitored with small thermo-loggers (“thermo-buttons”, Appendix 4). After activating the internal clock, these units can be placed in the bottom of the nest. After retrieving them, the downloaded data will show the temperature profile in the nest and reveal incubation bouts and distinct cooling after predation or hatching/nest abandonment. The timing of assumed predation events show whether predation occurred during the day or the night, thus hinting to the type of predator.

Last but not least, if you can observe the nest from a safe distance (e.g. from a car on a road), an incubating adult is a reliable sign of the nest being neither predated nor fully hatched.

1.2.10. Chicks

Mobility of chicks

EC chicks are precocial, meaning they leave the nest as soon as they are mobile enough to search for food. They are not fed by their parents and thus have to find their own food. Food during the first weeks of their life consists mainly of invertebrates taken from the vegetation or the ground. Later, they will also start probing the soil like adults for subsoil invertebrates. Hence, their feeding grounds may not necessarily be the same as their parents’. Chicks can move up to several kilometres a day, but their mobility seems to vary greatly between families, sites and regions (from stationary to “nomadic”). During their movements, chicks are capable of crossing ditches, rivers, streets, etc.

Chicks are well camouflaged and adept at hiding in vegetation. Hence, you probably will not often see them, but by interpreting the adults' aggressive behaviour (bark-like alarm calling even when danger is distant, alarm flights and quasi-attacks) you will be able to tell where families are (c.f. Chapter 3.3). It is essential to limit disturbance to a minimum during this crucial time, but you will have to balance this risk of disturbance with the risk of losing a family between visits because they move to other feeding grounds.

Mind your steps

In contrast to Northern Lapwing chicks (which hide **next** to things), EC chicks often crawl **under** things when hiding from perceived predators (i.e. including you). This makes them very hard to detect and easy to step on (see Fig. 23 below). Please be extremely careful when walking in areas where chicks can lay hidden under old grass, strings of cut silage/hay or dense vegetation. You will probably never notice accidentally standing on one. To make things more difficult, they also tend to crawl away for considerable distances under cover. This means that the place where you saw the chick disappear may not be the place where it actually is. **Therefore, these guidelines recommend you stay out of the vicinity of hiding chicks unless you have very good reason to go there.**

Figure 23. Hiding chicks are often hard to detect. Photo: Gerrit Gerritsen.

Hypothermia

Young chicks cannot fully control their body temperature and need to be brooded by their parents under cool and wet conditions. Disturbances can disrupt brooding sessions or prevent chicks from reaching a warm shelter. For this reason, you should avoid disturbing chicks in your study area when they can get cold and wet. Dew-wet tall grass on a chilly morning is probably fine for your boot-clad feet, but very challenging for EC chicks. During their second week in life, chicks will gradually increase their thermoregulatory capacity and the need for brooding disappears.

Clutch desertion

In some parts of the breeding range, adults stay with their chicks until they all leave the breeding area. In other part, adults leave well before their chicks depart. There seems to be a gradient from SW (where the adults stay) to NE (where adults abandon their chicks), but regional variation occurs. When adults leave before their chicks, the female tends to leave earlier than the male. In northern Sweden, females usually leave one or two weeks after the chicks hatched, while males stay with the chicks three to four weeks longer.

1.2.11. Marking of chicks

There are a variety of methods that allow us, with adequate training and consents in place, to capture and mark individual chicks in order to track their movements and determine their fate (e.g. whether they fledge or not, what predated them).

Common metal rings have unique codes engraved on them but are very difficult to read in the field. Whilst modern digital cameras (including digiscoping) may be a useful tool in overcoming this, vegetation often makes it very difficult to get a good view of rings in the field. Recapturing the chicks can also be an option but represents a labour-intensive and additional invasive action.

Colour rings and coded "flags" are much easier to read in the field and thus, increase the potential number of resightings and reduce the need for recapturing chicks. Compared with metal rings alone, colour rings/ flags comprise a greater burden for the chicks, potentially impacting on their welfare and survival.

Radio tags eliminate the need to make visual contact with the marked chick, but require manual triangulation. Tags are also relatively heavy and can get entangled in vegetation. Tags that are glued to the downy feathers will fall off during their first moult (which may be too soon for your objectives). Tags fitted with harnesses can be carried for much longer periods, which can be good for research but negative for the bird. GPS-tags are shrinking in size, weight and cost, and can now be used for large chicks (i.e. 3-4 weeks old). See Appendix 1 for comments and suggestions concerning GPS tags.

Chicks can be marked soon after hatching when they are still in or near the nest. Although this may have advantages (e.g. their age is known), we raise concerns about this practice, because (a) the relative weight of the ring(s) are much higher than for older chicks and adults, (b) small chicks lack the strength to pull rings through vegetation and (c) most of the rings (including valuable codes in colour schemes) will probably get wasted due to high predation rates. Additionally, cases of rings locking the movement of joints (between the tarsus and tibia or between tarsus and "toes") have been observed, and markers may even contribute to increased predation rates.

1.3 Data, statistical analyses and conclusions

Even if you are uncomfortable with scientific methods and numbers, we advise you to quickly read through this chapter. We think it will help you to improve your study design and to acquire a realistic view on your data. It may also help you to get the advice you may want/need. Experienced (bio-)statisticians may skip this chapter altogether.

1.3.1 "Uncertainty matters"

In all studies of real-world systems, the observations come with uncertainty ("error"). You can do a lot to reduce many sources of uncertainty, but never eliminate all of them completely. Usually, there are no ways to estimate the exact level(s) of uncertainty either. There are only two honest ways to deal with this inevitable situation: complete documentation of your study (transparency) and great cautiousness in the interpretation and publication of your results.

Many people argue that uncertainty is not a problem because the effects of the "errors" will even out over large sample sizes or long periods of time. Although this may be true in some cases, many errors are systematic and will not go away when the dataset grows. They cause bias. For example: a faulty scale on your ruler will produce bias, because, no matter how many lengths you measure, the readings will be wrong. Consequently, bias spoils the outcome of your study. The good news is that good planning based on solid knowledge of the study species and its environment can reduce or even eliminate several sources of bias (Box 1).

Uncertainty tends to grow when you combine multiple measurements, e.g. when you divide the number of territories by the size of your area to create a measurement of density of territories (a composite measurement). In these cases, the uncertainties do not just sum up but rather multiply. Methods to handle this statistically exist, but are beyond the scope of these guidelines.

1.3.2 Observation effort

Almost certainly, you will make more observations when you spend more time or cover a larger area, i.e. when your observation effort increases. When undertaking comparisons, the amount of effort must therefore be taken into consideration. It is wise to harmonize effort (e.g. apply observation bouts of fixed duration), but sometimes this is not possible or feasible. In those cases, you must adequately document and present all relevant measurements of effort in your analyses and publications.

Box 1. Potential sources of bias in EC studies

There is a complex and interrelated set of factors that can cause bias in the results of your EC study. Here we present six classes.

Search-bias
Your chances of finding an EC (or their nests or chicks) depend on **where** and **when** you search for them. The outcome of your survey will depend on the quality of your where-and-when-to-look choices. Unfortunately, many of these choices are made unconsciously or based on inadequate information.

Detection-bias
Even when the effects of search-bias are minimized, the conditions for actually detecting a bird (or nest or chick) vary. You should recognize aspects like weather conditions, topography, vegetation and objects blocking sight. This detection bias is especially important in point-counts and chick counts.

Behaviour-bias
The behaviour of the EC also affects the chances of detection. There are general and individual behavioural traits. You will gradually learn how 'your' EC behave and ideally, this learning process has come a long way before you start your survey.

Status-bias
Nests and eggs do not *behave* in the proper sense of the word, but they affect the way parent EC behave on and around them. For example, a nest during the egg-laying phase is much harder to find than a nest with an incubating parent that can be seen on or leaving the nest. Nesting attempts of different individuals may not be synchronous even in a single landscape.

Observer-bias
You are probably aware of the fact that some observers systematically see more or different things than other observers. Part of this is because our observation skills differ, but also because we interpret what we see differently. Where some see a pair when two birds walk together, others may cautiously report them as just two birds. Experience can improve the quality of these judgements, but in many cases, interpretations are never challenged and thus, conserved. In multiple-observer studies, the possible effects of observer-bias need to be recognized.

Effort-bias
Regardless of the quality of the observer, the amount of time spent on observing EC will affect the data set. This is particularly important to bear in mind when you plan to use public observation databases or the opinions of the public. Unfortunately, most people do not document their time in the field and thus, e.g. the notion "EC were much more common when I was a child" could be founded either on many more outdoor hours in the past or a real decline of the EC population in recent times.

1.3.3 Unobserved individuals

By human nature, we tend to ignore things we do not observe. The EC is a large and vocal bird of open places and consequently, relatively easily observed. This holds for many situations and situations, but not always – and especially not during the breeding season. Thanks to their colouration and behaviour, EC can manage to avoid detection surprisingly well. This ability varies over the day, over the season and between sexes. During the peak of display activities (early in the season and early in the day), you can expect to detect the vast majority of the birds present, but even then, some individuals may be foraging much farther away. During periods with less or no display activity, on the other hand, a significant proportion of the birds can hide in tall vegetation, in depressions (e.g. in dry ditches) or by sitting down. Conditions like strong winds can make birds seek shelter or sit down (instead of spending energy on keeping their balance against the wind). There are no simple rules for how to minimize and handle the numbers of unobserved birds, but awareness of the problem and finding solutions should be an active part of your study.

1.3.4 Statistical methods

Statistical methods for analyses of ecological data is a vast and rapidly growing field, but well beyond the scope of these guidelines. Suffice to say that there are free computer programs for almost any of the analyses you may want to use, e.g. in R (https://www.r-project.org/). R is a community-driven software environment, with support/discussion forums for all sorts of users.

For the statistically unexperienced, a good rule-of-thumb is to keep things as simple as possible. For example: although the proportion of females among EC observed over the season could be described by a logistic regression model, a plot of the real observations over time would be easier to understand and evaluate.

Finally, making your raw data public is a good way to help science forward. There are various free and non-commercial data depositories and pre-print publishing platforms, e.g. bioRxive.org.

1.3.5 Repeated measurements and confounding relationships between observations

In your study, you probably want to repeat observations (e.g. in successive years) and, for logistical reasons, cluster your activities in time and space. This often violates the requirements of traditional statistical methods and can easily lead to faulty conclusions. There are plenty of suitable statistical solutions for this, but you need to make the right choices. If modern (bio)statistics is not your field of expertise, ask for advice. Help from an experienced researcher in your own or a nearby discipline is probably a preferred choice, but an internet search can be a good start. Key words are “repeated measurements”, “autocorrelation” and “randomization”.

1.3.6 Trend analyses

Trend analyses are common statistical methods to extract information from repeated observations, e.g. a series of counts over time. Make sure to use a trend analysis model that matches your data (the prerequisites vary). Many implementations assume that individual observations are true values (without error), but in reality, they seldom are. You can cope with this (at least partially) with advanced modelling methods, but these methods often have other disadvantages. The best way to deal with these problems is to (a) describe your methods carefully, (b) present your raw data, (c) discuss the uncertainties in the publication and (d) tone down the conclusions.

1.3.7 Is more always better?

Intuitively, we expect the quality of our dataset to increase with a growing numbers of data points. Although this may be true in some cases, the “more-is-always-better” doctrine is not flawless.

Example 1. Enlarging the study area is one way of increasing your dataset. This enlargement may be beneficial, but a larger area will likely encompass more variation in habitat features. If these habitat features correlate with EC densities or reproductive success, the resulting (larger) dataset may be more ambiguous and relevant conclusions harder to make.

Example 2. Adding another year to a time-series is often wise, but, like area enlargement, this may introduce confounding variation when conditions change over time (e.g. through the introduction of a new agricultural crop or a ban on predator control). You may not always be aware of these changes, and if you are, you need to control for them in the study design and the analyses (e.g. by measuring them and adding them in your models as co-variates).

From a resource management point of view, more data always comes at a cost (time or money). In most cases resources are scarce and thus, you have to make a cost-benefit analysis before spending yet another hour or penny. Spending additional resources have to pay off. Although it may be hard, at some point in time you just have to conclude “enough is enough!”.

Finally, a major drawback of chasing the perfect/infinite dataset is that your results are likely to get “stuck in a drawer”. Bringing your findings to the world is important for you, for science, and, hopefully, for EC conservation and management. Do not wait too long! There is neither a **perfect** dataset nor a **perfect** publication.

1.3.8 Conclusions and generalizations

Assuming your observations are of good quality and your analyses made correctly, you can draw valid conclusions from the results of your survey. These conclusions will be “true” for the investigated population, the area and the time-frame of your study.

If you want to claim that your conclusions also apply in other areas, time-frames or conditions (i.e. make generalizations or inferences), compliance to basic scientific rules is necessary to convince your audience. Sampling strategy, sample size and transparency are key factors. In case you plan a serious (potentially costly) study, make sure the study really matches the intended outcomes, even after scientific scrutiny.

2 Survey methods for breeding EC populations

In this chapter, we present methods to study numerical features related to the size of EC populations. Two methods target whether or not breeding birds are present in the study area (Chapters 2.1.1 and 2.1.2) and three methods aim to quantify the numbers of individuals (Chapters 2.2.1 and 2.2.2) or breeding territories (Chapter 2.2.3).

PRESENCE SURVEYS

- Value: True or (1) if a EC was present in the study areas; False or (0) if no EC was observed.
- Observations from points for fixed time-bouts (e.g. 5min) or from short (1-5km) routes.
- Standardize your effort and avoid poor weather (e.g. fog or rain).
- Document well how you count: from a car or walking, with optical aids, etc.
- Avoid public datasets because only presence, not absence is reported.

PRESENCE-ABSENCE SURVEYS

- Same method as presence study with the addition that a False (0) value can only be obtained when it **is highly unlikely** that any EC was present (difficult to proof; requires extensive fieldwork, documentation and experience).
- Make sure to observe your study area thoroughly during a sufficient time period in good weather conditions.
- True absence is more likely if surveys are repeated (within a breeding season).

POINT COUNTS

- Value: total number of EC observed from a certain point during a certain time-frame (e.g. bouts of 5min.).
- Results can be compared between seasons if standardized (same points, timing, duration).
- Counts of pairs are not advised because they exclude unsexed individuals.

AREA SEARCHES

- Value: Total number of EC observed in a certain area while moving through the area.
- Route should include all EC present in the study area.
- Avoid the risk of double counts.

TERRITORY MAPPING

- Value: Territories mapped based on a series (commonly 4) of visits during a single breeding season.
- Interpretation of “territory” should be based on a good, context-based understanding of the ecology of EC.
- Code every territorial behavior and signs of breeding during each visit with a standardized coding-system.
- Finalize the mapping by clustering all observations to estimate territory numbers in the study area.
- Territory numbers can be compared between sites, years and time-periods.

2.1 Surveys of presences and presence-absences

*Surveys of presences or presence-absences are a good and cost-effective way to start EC population studies. These two types of surveys may seem confusingly similar, but they are very different indeed, because in the latter, emphasis is on ensuring that absences of **observations** of EC really relate to absences of EC (see Chapter 2.1.2 for details).*

Shortly after arrival to the breeding grounds EC show territorial behaviour (like display flights, singing, mating, etc.) more often than during the incubation period, and thus, early surveys are more effective than later ones. For presence or presence-absence surveys during the chick-rearing period: see Chapters 3.2.2 and 3.3.

The contents of public observation databases are a tempting source of presence data, but we strongly advise you to use these data with great caution (Box 2).

2.1.1 Presences

Definition

This unit of measurement is one (1) if at least one EC was observed within the study area during a certain period and zero (0) if no EC was observed.

Considerations

Although you could survey presences of EC over large areas, along long stretches and/or over long time-frames, we strongly suggest you observe for presences during short bouts of time and from either points or short stretches (e.g. 5 minutes from one point or along 1-5 km of road/track). You can also combine repeated surveys of presences in a single study design (same duration, same points/tracks but different occasions).

You can improve your results by standardizing effort e.g. fixed observation periods (e.g. 5 minutes), and fixed observation points, routes or search areas. Standardization of timing (during the day and/or season) and avoidance of poor weather conditions (e.g. fog or rain) will also improve the quality of your results.

Finally, you should carefully document how you made your observation(s) (from a car, while walking, with/without optical aids, etc.), as your obvious presence can influence EC behaviour and hence, detectability.

Method

Scan for EC within the pre-set time-frame and/or transect/area of your choosing (the temporal and geographical limits respectively). As soon as you observed an EC within these limits, you can stop observing, because presence is one and cannot change as a result of further observation. If no EC was observed when you reached these limits: presence is zero.

If you do not want to apply pre-set limits, you can still use this method, but need to document where and when your observations were made.

Box 2. Presence data from public observation databases

Huge amounts of information are available in public observation databases. These databases usually contain reports of presences only, because absences (none observed) are usually **not** reported. This makes these observation databases unsuitable for presence-absence studies. For studies of presences, the main issue is unknown effort, because effort is usually not reported. This means, for example, that site A with 150 reported observations may not be better than site B with 50 observations in case birdwatchers have spent tenfold more observation time in site A than in site B. Another problem is redundancy when two or more observers have reported the same bird. Altogether, it is often much better to make your own survey than to rely on the observations of others.

2.1.2 Presence-absences[3]

Definition

In presence-absence surveys, the result is one (1) if at least one EC was observed within the study area during a certain period and zero (0) if no EC was present. In contrast to presence surveys, a zero score (absence) can only be reached when it was **highly unlikely** that there was any EC present.

Considerations

In addition to the considerations mentioned for presence-studies, the following applies:

While an observation of the presence of EC is unproblematic, the observation of absence is not. It usually takes a good deal of fieldwork and extensive documentation to convincingly present a record of absence. Although EC are often easy to observe, it is extremely difficult to “prove” that the species was absent just because you did not observe it. We suggest you are very careful with the use of the presence-absence label and, in case you conducted a true presence-absence study, to extensively report your study method.

During the incubation period, some individuals sit extremely tight on their nest. In tall (>15 cm) or tussocky vegetation, these individuals can be extremely hard to detect, e.g. by scanning a field with optical aids from a distance, and even from astonishingly close range (<5 m) when walking a field. Consequently, we advise to avoid surveys where presence-absence observations are only made during the incubation period.

[3] Some scientists claim that true presence-absence studies do not exist, because it is almost impossible to prove absences. They suggest the term presence-quasi absence. Although this may be philosophically appealing, we argue that, in a well-designed study, the absences of EC are likely enough to qualify for the presence-absence label. The description and implementation of an appropriate method is paramount.

Method

In addition to the methodology of surveys of presences (Chapter 2.1.1), you must design, apply and communicate an efficient scheme for the reduction of potentially unobserved EC. This often means that the observer (you or a co-worker) must have a good view from close range (e.g. <100 m) over all parts of the study area during a sufficiently long period of time (e.g. 5 minutes). It is also important that you explicitly avoid unfavourable conditions, e.g. fog, rain or strong winds.

If the numbers of EC in your study area are small and/or EC are difficult to observe, you could repeat the presence-absence survey a number of times in the same breeding season. If no EC were observed during **every** occasion, true absence is more likely than absence based on observation from one occasion only.

2.2 Surveys of abundances

EC numbers can be counted in many ways, but to ensure compatibility between surveys, we suggest you choose one of three standard methods: point counts, area searches and territory mapping (c.f. Bibby et al 2000, Sutherland 2006, Brown & Shepherd 1993). In territory mapping, territories are often seen as proxies for breeding pairs (c.f. Box 3).

2.2.1 Point counts[4]

Definition

The unit of measurement is the total number of individual ECs observed from a certain point during a certain time-frame. Typically, a survey consists of a number point counts within a study area.

Considerations

The results of point counts can be compared between breeding seasons if they are conducted in a standardized way, i.e. same point, same timing and duration and, preferably same observer (c.f. Chapter 1.3).

If the results of a set of point counts are intended to represent a larger landscape (larger than the total area covered from the points), then the points need to be randomly dispersed across that landscape. Points in a regular grid can be used as a semi-random alternative. Random or semi-random sampling can be logistically challenging or not feasible (e.g. due to access restrictions). In structurally "simple" landscapes (e.g. flat, open landscapes with a dense network of roads and tracks), point counts from easily accessible points can serve as an acceptable quasi-random sample of the entire landscape.

Your count results will depend on the visibility of the terrain and vegetation, and on the detectability of the birds. To control for the influence of terrain features, you must make sure that you either cover the same area or count from the same points/transects. To cope with the changing detectability of the birds, you should standardize the time of day (across a season) and the time(s) of the season (between years).

The duration of the observation period at each point is a trade-off between maximizing the count numbers and efficiency. Bouts of 5 minutes are common in European monitoring schemes e.g. the Swedish Monitoring Scheme (http://www.fageltaxering.lu.se/english).

Method

All EC within the study area observed from pre-selected points under a fixed period are counted. We recommend 5 minutes of observation per point and a minimum of 10 counting point.

[4] Transect counts can be seen as an extension of point counts and are suitable for areas with low population densities where point counts would generate a large proportion of zero-counts. Transect counts are less standardized than point counts, though, because they include more variables than point counts (i.e. speed and transect length). For details: see Bibby et al 2000.

Box 3. Counts of pairs

Definition

Counts of pairs are an extension of counts of individuals. Pairs of one female and one male with a supposed pair bond are included, but all other individuals are excluded.

Considerations

It is not always possible to determine the sex of individual EC by field observation (Chapter 1.2.1). Consequently, a proportion of observed EC will remain unsexed and are thus, excluded from the pair count. You can neither control nor predict this proportion in your study design.

It is not always possible to confirm the pair bond between a female and a male. This also reduces the numbers of pairs in your survey. A female and a male present in a certain area at the same time does not guarantee they are a breeding pair.

Finally, pairs are not unambiguously linked to reproductive effort and output, and thus, not very useful for studies of reproduction (c.f. Chapters 1.2.4).

Based on these considerations and despite its common use, we advise against the use of the *pair* measurement in surveys of EC breeding populations and reproduction. This measurement does not add reliable information to what counts of individuals, area counts or territory mapping can provide.

2.2.2 Area searches

Definition

The unit of measurement is the total number of individual ECs observed within a certain area while moving through the area in such a way that all EC present have an adequate chance to be detected.

Considerations

The route of the observer through the area must facilitate the observation of a large proportion (ideally all) of EC present. Detection ranges will depend on landscape features and the behaviour of the birds (c.f. Chapter 1.2). As a rule of thumb, a detection range of 100 or 200 m can be used, translating into maximum distances between any part of the area and the observer of 100 and 200 m. respectively (the latter value for flat and open landscapes).

When the shape and the size of the area requires the observer to move to and fro across the landscape, a risk of double-counts arises, highly dependent on population densities. An adequate strategy for the avoidance of double-counts needs to be applied and reported. The use of coded notations on a map can be helpful, basically turning the area search into a single-visit territory mapping (c.f. Chapter 2.2.3).

Area searches during the main incubation period should be avoided, because some incubating EC sit tight on their nest.

During your area search, you may encounter birds which are not in your area but which responded behaviourally to your presence (or to the behaviour of other birds responding to your presence), exhibiting a type of "predator mobbing" behaviour. In these cases, you must make an informed guess as to how many individuals were actually in your survey area, and excluding those which were drawn in from outside of the survey area.

Method

The selected area is walked under good conditions for observing breeding ECs and in a way that adequate area coverage is guaranteed (Brown & Shepherd 1993). All observed ECs within the area are counted, but double counts are avoided.

2.2.3 Territory mapping

Definition

In this method, breeding territories[5] are documented based on a series of visits during a single breeding season. The spatially explicit information gathered during the individual visits is "interpreted" according to specific rules. Only territorial behaviour and direct signs of breeding are used (c.f. Bibby et al. 2000).

Considerations

For non-passerines in open landscapes, four visit schemes are common, but 1-3 visits are sometimes used as well.

The territory concept is the core of this survey method. For comments on the validity of the territory concept in EC: see Chapter 1.2.4. In the field, you will interpret your observations within the territory-mapping framework. Make sure your interpretations are based on a good, context-based understanding of the ecology of the EC (Chapter 1.2 for comments and suggestions).

If your study site is surrounded by truly unsuitable EC breeding habitat (e.g. sea or extensive forests), EC observed just outside the study area can be included in the mapping process. If your study area is bordering suitable habitat, then you need to be apply strict rules for which observations to include and which ones to exclude (c.f. Bibby et al. 2000).

Method

During each visit, all observations of territorial behaviour and direct signs of breeding (e.g. nests or chicks) are marked on a physical or electronic map (the "field map"). We suggest you make four visits and use a standardized coding system (e.g. Bibby et al. 2000), with the addition of a zig-zag arrow for display-flight paths. If you use other additional or modified codes, these should be made explicit in the meta-data and the publication.

Shortly after each visit, you must transfer your new field data to the aggregated map (the "species map"). This is particularly important in case you mapped multiple species on your field map. (Field maps with many species tend to become messy and hard to read without fresh memory.)

In the final step, observations on the species map are "clustered". These clusters represent the territories. There are strict rules for how this clustering should be done, depending on the number of visits. We suggest to follow these rules closely, but, at the same time, to realize that rules can never handle a complex reality without the aid of an informed human (= you). If you know your species well, your interpretations will be the best available.

The outcome of the clustering process is an estimated number of territories within the study area during the actual breeding season. We advise you to always present this number of territories with a full site description (including area), the year(s) of study and the surveyor's name(s).

Numbers or densities of territories can be compared between sites, years and time-periods (Chapters 1.3.5 and 1.3.6).

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[5] Breeding territories are not equivalent to home ranges. Even during the breeding season, individuals can visit places outside their breeding territory, These places are part of their home range but not their breeding territory.

3 Surveys of reproduction

Reliable data about reproduction are the key to understanding observed populations trends and for making predictions of future trends. These guidelines deal with reproduction at the population level, not the reproductive success of individuals (for e.g. fitness or pedigree). Although individual-level reproduction studies could shed light on demographic aspects of populations (e.g. recruitment and dispersal), these studies and the methods they use tend to be very specific and expensive, and thus, out of reach for most survey projects.

Ideally, population-level reproduction surveys should quantify the production of new first-breeders (= recruitment) over a long (>10) sequence of years. In reality, the vast majority of studies survey the number of eggs and/or chicks produced within a breeding season, albeit often under a series of years. Information about pre-breeding survival, juvenile dispersal and true age of first breeding are rarely available, but new technologies (e.g. long-term GPS tags) are starting to provide such information.

CLUTCH SIZE

- Aim: survey clutch size, which is the maximum number of eggs (usually 4, but 3-5 also occur).
- If a nest with <4 eggs is found, revisit again after 2-3 days to confirm clutch completion (4 eggs or same number as the prior visit).
- Single visits cannot be considered because a nest might not be a full clutch yet, but a minimum number of visits is desired to reduce disturbance.
- Mark the nest only if necessary (e.g. for re-finding or protection from agricultural practices).

NEST SURVIVAL

- Aim: Estimation of percentage of successful nests. Value: True or (1) if at least one chick hatches; False or (0) if no chick hatches.
- After finding a completed nest, revisit the nest close to, or after the estimated hatching date.
- Determine nest fate (successfully hatched, predated, deserted, destroyed, etc.) by carefully investigating the nest site.
- Nest-survival models can be used for more detailed statistical analysis.

EGG SURVIVAL and HATCHING SUCCESS

- Aim: Estimation of percentage of hatched eggs. Value: (1) if an egg hatched successfully and (0) if it failed.
- Egg survival may vary over the breeding season. Collect good date over the entire period (ideally starting from clutch completion).
- For accurate data, visit nests every 3-5 days, but keep in mind negative effects of nest visits.
- Models for daily survival rates can be used for more detailed statistical analysis.

CLUTCH SURVIVAL

- Aim: Estimation of percentage of successful families. Value: (1) if at least one chick survives from one observation event to another and (0) when all chicks of a clutch fail to survive.
- Behavior of parent birds can be used to confirm the presence of at least one living chick (survival of individual chicks is not measured).
- Method relies on detection rate of families and hence is prone to errors.

CHICK SURVIVAL

- Counting chicks is difficult and, for reasons of good comparability, should be standardized (same places during the same timespan and same day of the season).
- Repeated counts during one season increase the chance of detecting chicks and hence strengthen the data.
- Theoretically, repeated counts can be used to estimate individual chick survival.
- Individual markers on chicks can be used for more detailed studies, but are very invasive.

GUARDING ADULTS

- Guarding adults are much easier to map and hence their presence can be used as a proxy for the presence of chicks (or a nest).
- Behavior of parents can be described as (1) distressed (alarm calling, flying around any danger, distracting intruders, etc.) or (2) guarding (upright, alert, sometimes sitting on posts). Both behaviors are good indicators and can be mapped easily.
- Adults tagged with GPS devices can be used for more detailed studies, but catching and tagging is very invasive and requires permits and experience.

3.1 Surveys based on nests[6]

3.1.1 Clutch size

Definition

Clutch size is the maximum number of eggs present in a nest.

Considerations

At first visit, the clutch may still be incomplete and thus, it is necessary to confirm the maximum number of eggs through repeated visits. Data from single visits must be excluded from clutch size analyses.

Theoretically, partial predation might outweigh the laying of new eggs and thus, disguise nests to which eggs are still being added, despite the observation of equal numbers of eggs at subsequent visits. Partial predation is an uncommon phenomenon, though, and as a result, this problem is virtually hypothetical.

A minimum of nest visits should be preferred for the sake of the welfare of the adult birds and for reducing possible risks of predation and desertion (= abandonment).

Clutch sizes of more than four eggs are rare, but clutches of less than four eggs are fairly common (c.f. Chapter 1.2.5). From this, an acceptable strategy could be to consider clutches of four eggs to be complete even without a confirming revisit. In case data from these clutches are included in the results, this should be explicitly mentioned in the report.

Method

After the first visit to a nest with at least one egg, you need to revisit the nest until you have confirmed that the clutch is complete. The clutch is complete when the number of eggs is the same as the previous visit; then, no further visits are needed for the clutch size survey. In contrast, if the number of eggs increased upon the second visit, then further visits are needed to confirm clutch size. The rule-of-thumb “one egg every one or two days” and the “normal” clutch size of four eggs can help you plan your re-visits.

There is a trade-off between improved data quality through repeated nest visits versus increased disturbance and possibly increased risk of predation and desertion. Drone technology has the potential of eliminating this trade-off, but currently, drones come with technical and economic challenges for many EC survey projects (see also Chapter 1.2.6).

In certain environments (e.g. tall grass swards or heath), it may be necessary to mark the nest site so re-finding the nest is easy and quick (c.f. Chapter 1.2.7).

[6] When you decide to perform a study on nests, you may also want to consider the extension program described in Appendix 6.

3.1.2 Nest-success (see also Box 4)

Definition

Nest-success is one (1) when a nest "survives" from the time the clutch was completed until the hatching of at least one egg and nest-success is zero (0) when no eggs in the clutch make it to hatching. Over a set of nests, the individual successes and failures combine into a probability between zero (if all nests failed) and one (if all nests were successful). This probability can also be expressed in percentages, e.g. 60% if six out of ten nests had eggs that hatched.

Considerations

This measurement is only vaguely linked to reproduction, because it does not take into account factors like clutch size and partial predation.

We suggest you put much effort into early detection of nests, because failing to detect nests that were predated or damaged early has a strong influence on the population-level value of nest-success.

For nests on agricultural land, farming activities (e.g. mowing, ploughing, grazing) can affect the nesting site. In many cases, the fate of the nest will be apparent (e.g. all nests are destroyed during ploughing), but sometimes it is not (see Chapter 1.2.8).

Method

First, you need to find the nest and then verify that the clutch was complete (c.f. Chapter 3.1.1). Second, you need to check whether or not at least one egg in the nest hatches. Unless you can use technical monitoring devices (e.g. "thermo buttons", Appendix 4, or wildlife cameras, Appendix 5), you need to revisit the nest to verify success or failure (c.f. Chapter 3.1.1). Alarm-calling adults and chicks near the nest site are indicators of nest-success, but are not fully reliable (c.f. Chapter 3.3.1).

Successful nests have characteristic eggshell remains in or next to the nest (Fig. 9 & 11) and, usually but not always, alarm-calling parents nearby. All other nests can be considered to have failed.

Box 4. Nest-survival

At a population level (i.e. not for individual nests), nest-success can also be estimated from daily survival rates and the expected (average) duration of incubation. The benefits over nest-success surveys (Chapter 3.1.2) are that there is no need to monitor the full egg period and that data from multiple nest visits can be used. The disadvantages are the uncertainties caused by the underlying assumptions (e.g. about incubation period length and equal predation pressure across the incubation period) and the need to apply complex statistical models (e.g. Mark, Popan and various R-packages) on larger sample sizes (typically more than 50 nests). For most surveys of EC reproduction, we do not expect nest-survival surveys to add significantly more information about EC reproduction than nest-success surveys do. We also expect readers determined to make a nest-survival survey to have or be able to acquire the knowledge of how to design, conduct and analyse such survey.

3.1.3 Daily egg-survival rate and hatching success

Definition

Hatching success is one (1) when an egg hatches successfully and zero (0) when it failed. Over a population of eggs, these successes and failures combine into a probability between zero (= no egg survived) and one (= all eggs survived), alternatively 0 - 100 %.

In addition to direct observation, population-level hatching success can be estimated from data on daily egg-survival[7]. The more days an egg has been observed to survive, the stronger it contributes to the rate of estimated hatching success. Average daily survival is then related to the estimated length of the incubation period in calculations of estimated hatching success. These calculations apply certain assumptions for the uncertainty of how long the egg survived between an observation where the egg was present and the next when it was absent or dead (e.g. Mayfield 1975, Johnson 1979, Aebischer 1999, Hazler 2004)[8].

Considerations (see also second and third consideration in Chapter 3.1.2)

Because egg survival rates may vary over the breeding season, it is desirable to collect good data from the entire egg period.

In theory, measuring egg-survival starts at the time when the individual egg was laid, but most statistical applications use clutch completion as the starting point. If the survival of individual eggs is important for your survey, you need to individually mark each egg in the nest.

Because predated nests are difficult to find and their numbers of eggs impossible to quantify, predated eggs will be under-represented in egg-survival/hatching success surveys (especially for nests that were predated early and thus, had less chance to be found). As a consequence, levels of daily egg-survival and hatching success tend to be over-estimated.

[7] See Chapter 3.1.2 and Box 4 for similar measurements for nests.

[8] Please note that these references use a different terminology than the one used in this document.

Method

For nests found during the egg-laying phase, timing of clutch completion and the onset of incubation can be observed with high accuracy. For nests found with complete clutches, you need to establish how far into the incubation process the eggs have come (Appendix 2 & 3). From repeated control visits or technical monitoring (Appendix 4 & 5), you then collect data on the number of days until hatching or predation/destruction. Unhatched eggs are excluded from the analyses. Eggs from nests with partial predation should be included, but with a different number of days for eggs with different outcomes.

Theoretically, you could schedule your check-up visit to after the estimated hatching date, but we recommend a revisiting scheme with 3-5 day intervals, unless technical surveillance is possible (Appendix 4 & 5).

For small datasets (< 20 eggs), the proportion of hatched eggs (the simple measurement of hatching success) may be the adequate outcome to report. For larger datasets, you probably prefer estimates of hatching success based on daily egg-survival rates (or the survival rates as such). The Mayfield method is a relatively simple way to calculate daily survival rates (Mayfield 1975, Johnson 1979), but this method is sensitive to long intervals between observations. Even modern survival analyses methods (e.g. Mark and Popan) benefit from frequent nest visits, but are generally more robust. These models require computer programs and careful selection of various parameters (based on various assumptions) and thus, adequate statistical knowledge.

Box 5. Fledging success

In analogy with studies on nidicolous birds, the term "fledging success" is sometimes used in wader studies. We advise against the use of fledging success, because fledging is ambiguous in EC. If "fledging" is meant to describe, "leaving the nest" (as it does in nidicolous birds), then hatching and fledging are basically the same thing in waders, because the time between hatching and leaving the nest is very short. If "fledging" is meant to describe, "becoming capable of flight", then this is a gradual process with unclear transitions, i.e. from being able to lift a few centimetres to flying a few metres to flying several hundreds of metres to being able to leave the nesting area altogether. Without a well-defined and measurable interpretation of fledging, fledging success does not contribute to our understanding of reproduction in EC and the term should be avoided.

3.2 Chick numbers and survival

Numbers of chicks are a better measure of reproduction than numbers of nests or eggs, because they already survived a risky period. Unfortunately, counting chicks and following their survival is often difficult, but results from good count and survival surveys are very important for conservation and management of EC populations.

Chick survival can be monitored at clutch or individual level (Chapter 3.2.3 and Chapter 3.2.4 respectively). For methods using parents as proxies for the presences of chicks: see Chapter 3.3.

3.2.1 Chick counts

Definition

The number of chicks observed within the study area during a surveying event.

Considerations

Chicks observed during the later stages of the chick-rearing period are more valuable than chicks observed early, because the chances of overall survival increase over time. Consequently, synchronized timing is vital for comparisons of count results between years or sites.

If different parts of the study area need to be surveyed on different occasions, the time-frame of the full surveying event should be as short as possible. If not, early visited parts will suffer higher chances of subsequent losses (e.g. to predation) than parts visited later.

For issues on detection rate etc.: see Chapters 1.3.3 and 2.2.1.

Repeated counts during a single season can either strengthen the quality of your data (by using the highest values of several counts within a short period of time) or provide data for a chick survival survey (c.f. Chapter 3.2.3).

Method

Count the EC chicks in your study area, maybe in the same way you counted adults (c.f. Chapter 2.2.1).

The time of the day and weather conditions (Chapter 1.1.3) will have a large impact on the results. Avoid adverse weather (e.g. rain and strong winds) and focus on periods when detection rates are high in your specific environment.

For survey schemes planned to cover multiple years and/or multiple areas, choose clear rules for standardization, e.g. “Count from the road between X and Y between 9 and 11 PM during the first week in July, but not when it rains or blows more than 4 Beaufort ≈ 10 m/s”.

3.2.2 Post-hatching clutch survival

Definition

Post-hatching clutch survival is one (1) if at least one chick in the clutch survives from one observation event to the next, and zero (0) when all the chicks in the clutch failed. Over a population of clutches, these successes and failures combine into a probability measurement between zero and one (or can be expressed as a percentage). This method is analogous to the method of surveying nest success (Chapter 3.1.2).

Often, the behaviour of parents can be used as a proxy for the presence and survival of chicks, see Chapter 3.3.

Considerations

It is crucial that observations relate to the same clutches. If a later observation relates to another clutch than an earlier observation, the survey result will be erroneous.

Obviously, this method does not provide information about the survival of individual chicks, and the results cannot be used in traditional survival models.

The reliability of this method relies heavily on the detection rate of the chicks in the area. When all present chicks in a clutch remain **un**detected, the clutch is falsely recorded as failed.

See also considerations in Chapters 3.2.1 and information in Chapter 1.2.8.

Method

Survey the chicks in the clutches within the study area. If a clutch is still represented by at least one chick, this clutch has survived successfully, but if no chick was re-found, the clutch failed.

3.2.3 Chick survival from repeated counts

Definition

Chick survival is one (1) if a chick survives from one observation event to the next and zero (0) when it fails. Over a population of chicks, these successes and failures combine into a probability measurement between zero and one (or as a percentage between 0% and 100%). Survival can either be expressed per day ("daily chick survival" – essentially the odds of making it through to the next day) or for a specific period between life-history events (e.g. from hatching to the onset of post-breeding migration).

Considerations

Without individual markers, it is usually impossible to identify individual chicks. If local population-level survival can be accepted as a measurement of individual survival at large, this method is fine. If not, individual markers are a must (see Chapter 3.2.4).

Chick survival is likely to vary with age after hatching. If periods with high mortality (e.g. the first days after hatching or spells of bad weather) are over-represented in the survey, your results will under-estimate chick survival. The opposite is true when periods with low mortality are over-represented. If possible, survival should be surveyed over the full length of the chick-rearing period.

The prerequisites of this method collapse when chicks move in and out of the study area, in particular when they start making long flights. For this reason, data collection for this method should be restricted to the time-frame when most chicks are incapable of flight. Even then, the problem of chicks possibly moving in and out of the study must be dealt with (c.f. Chapter 1.2.10).

See also considerations in Chapters 3.2.1 and information in Chapter 1.2.10.

Method

Count the chicks in the study area in the same way on at least two occasions (see Chapter 3.2.1 for details). If all or a great majority of the nests were surveyed for hatching success (Chapter 3.1.3), the outcome of this survey (total number of hatched chicks) could also be used as a starting point for chick survival analyses.

In its simplest form, chick survival is calculated from the latter count result as a proportion of the former. For example, if 30 chicks were observed on the first day of counts and 15 chicks were observed two weeks later, then chick survival over the two weeks would be 0.5 or 50%. If a third count yet another week later (in the same area, of course!) resulted in six observed chicks, then the survival rate for this last week would be 0.4 or 40%. For the full 3-week period it would be 0.2 or 20%.

If a latter count produces a higher number than an earlier one, the calculated survival rate would exceed 100%, which is impossible. If this occurs, you should set the survival rate to 100% and try to figure out whether this faulty result was caused by (a) emergence of chicks from late clutches, (b) more undetected chicks during the initial count than the following one, or (c) movements across the borders of your study area.

3.2.4 Chick survival from mark and recapture/resighting

Definition

Chick survival is one (1) if a chick survives from one observation event to the next and zero (0) when it fails. Over a population of chicks, these successes and failures combine into a probability measurement between zero and one (or as a percentage between 0% and 100%). Chick survival can either be expressed per day ("daily chick survival" – essentially the odds of making it through to the next day) or for a specific period between life-history events (e.g. from hatching to the onset of post-breeding migration).

Unlike chick survival from repeated counts, this method provides information about the survival of individual chicks.

Considerations

This methods requires chicks to be individually marked and thus, caught and handled. Catching and handling is an invasive procedure for the chicks and stressful for the parents. This negative impact may be acceptable when the outcome of the survey is clearly beneficial for the 'greater good' of EC conservation. You need to endeavour to minimize the harm/distress and optimise the scientific output (e.g. the number and interval of readings per marked bird). See also Chapter 1.1.5.

There is a variety of technologies available for tagging chicks (and adults), each with pros and cons (Chapter 1.2.11). There is also a trade-off between the wish to mark chicks as early in life as possible versus their welfare and survival (Chapter 1.2.10).

Method

Search your study area for chicks to mark and then to recapture/observe again. The fewer living marked individuals you miss (= do not observe) the better. How to optimize detection rates depends on your habitat and the objectives of your survey (c.f Chapter 1.3.3).

For the interpretation of your results see Chapter 3.2.3 (Method), but in this case, survival is recorded at the individual level and could possibly be linked to specific parents, nests, siblings, sites, etc.

3.3 Adults as indicators of breeding success

Nests and chicks are difficult to monitor, but adults displaying "parental behaviour" can be used as a proxy for the presence of a nest or chicks (Box 6, Chapter 1.2.10). The presence of "parents" can thus be used for a snapshot description of the number of successful breeding attempts or to describe nest and/or chick survival through repeated observations.

Definition of breeding success

Breeding success is one (1) when a breeding pair[9] has a nest with eggs or at least one chick, and zero (0) when it lost its nest or all its chicks. Due to predation and other mishaps, many initial successes may turn into failures over the course of the breeding season, but early failures can also turn into successes through re-laying.

"Final" breeding success is only reached at the end of the breeding season when juveniles are near the onset of post-breeding migration (c.f. Chapter 1.2.10), and observations of breeding success prior to that stage (including eggs) should be viewed as "partial breeding successes". Consequently, the later partial breeding success is documented, the closer to final success it gets.

Box 6. Parental behaviour

Distressed parents
In response to a perceived hostile intruder, adults with nests or young chicks make intensive alarm calls (in flight or on the ground) and, when the intruder comes close, often display distraction behaviour on the ground (Fig. 24 & 25). Neighbouring parents often join in with these behaviours. Non-parents, on the other hand, utter no or few alarm calls, do not display distraction behaviour and will move away from the intruder instead of defending a certain spot. The downside is that parents need to be provoked to display alarm-behaviour and thus, you cannot observe this class of parental behaviour from a distance in a calm environment. Tracking adults' responses to predators can be helpful (Fig. 26), but usually, the approach of an observer is needed.

Guarding parents
When the chicks have grown larger and become more independent and mobile (from c. two weeks after hatching), parents spend much time guarding them from some distance. If available, parents use elevated lookout points from which they can overlook the landscape, and these guarding parents can often be observed from considerable distances. These lookout points can be tussocks, hillocks or ridges on the ground or human constructions (fence posts, sheds or barns). The advantage of surveying guarding parents over alarming parents is that you can do it from a distance without disturbing the birds.

Movement patterns of GPS-tagged parents
Location data from GPS tags with high temporal resolution (>6 reads per day) on adults can effectively disclose nest sites and parental behaviour during chick-rearing (Bracis et al 2018, Bracis 2019). In areas where females leave the breeding site earlier than males, GPS tags on males are preferred

[9] A territory can be used as a proxy for a breeding pair (Chapter 2.2.3). The concept of "pair" is discussed in Chapter 1.2.4.

Figure 24. Distraction display by parent (female) in response to nest intruder. Photo: Adriaan de Jong.

Figure 25. Distraction display by parent (female) in response to nest intruder. Photo: Adriaan de Jong.

Figure 26. EC and Northern Lapwing jointly attacking a Marsh Harrier.
Photo: Gerrit Gerritsen.

3.3.1 Distressed parents

Considerations

Alarm-calling adults may fly around for substantial distances around their nest or chicks. They also tend to follow you (or another intruder) when moving through the landscape. In dense populations, they can easily fly over multiple territories and become difficult to link to a specific nest or clutch.

Many chicks increasingly move around in the landscape when they grow older, and their parents with them (c.f. Chapter 1.2.10). If they move outside your study area, you may fail to detect them. In dense populations, it may also be difficult to separate parents from multiple nests or clutches.

Some individuals react fiercely while others keep calm until the pressure gets really high. In some EC communities, there is a much higher level of collective alarming than in others. These differences may be associated with differences in breeding bird densities between sites. Thorough observations and careful interpretations are needed for reliable results.

Method

Distressed adults or pairs within the study area are counted, all other individuals are excluded.

Depending on your objectives, you can choose the timing of your visit over the breeding season. With early visits, you will register more breeding attempts, but a proportion of those are likely to fail after your survey. Late visits will generate fewer observations, but these will be more likely to indicate final ("true") breeding successes than early ones. You can also deploy a scheme of multiple registrations per season for an estimation of survival of nests or chicks (c.f. Chapter 3.2.3).

For comparisons of survey results between years, a certain degree of standardisation is needed, e.g. visits halfway through the main chick-rearing period. In The Netherlands, counts of alarm-calling parents during the chick-rearing periods (end of May) are widely used to produce data for "Gross Territorial Success".

3.3.2 Guarding parents

Considerations

The rationale behind this method is that parents stay with their offspring, but abandon their guarding behaviour soon after all the chicks have died (de Jong 2017). The duration of the chick-guarding period seems to vary across the breeding range (Chapter 1.2.10). Overall, this means that presences and absences of guarding parents depend on the combined effect of chick mortality and adult departure.

You may find this method appealing because it is non-invasive. If there is a good network of roads and tracks in your study area, you can cover a lot of ground by observing from your bicycle or car (but see Box 1 for a discussion about search- and detection-biases).

Method

Travel through your study area and look for guarding parents. Evenings and early mornings are good periods, because adults spend more time feeding during daytime. Non-guarding adults rarely stand vigilant for more than very short periods.

In its simplest form, a single observation session will provide useful information, but we assume you plan a series of observations, within a single breeding season and/or over a number of years (c.f. Chapter 1.3.5). If so, we suggest you standardize your route and time-schedule to improve the power of comparisons of the results (see also Chapter 1.3.6).

3.3.3 Movement patterns of GPS-tagged parents

Considerations

GPS tags provide snap-shot data of where the bird was at the time of GPS-fixation. Where the bird was between these fixes is unknown, but from physics of locomotion, the area of likelihood can be estimated. Here, time between fixes and thus, available for displacement, is crucial. Consequently, the interval between fixations determines the explanatory value of the position data set. Solar-powered GPS units rarely have power constraints during the summer months so the maximum number of fixes per day should be chosen for the purpose of this survey method.

Catching and tagging are invasive procedures and their use should be carefully evaluated in the light of animal welfare and research ethics (c.f. Chapter 1.1.5).

Method

Adults can be caught on the nest (after temporarily replacing the eggs with dummies!), in mist nets or in walk-in wader traps at feeding sites. For large operations, the use of cannon nets may be an option.

Make sure to use reliable tags with a low weight/performance ratio suitable for your objectives and your budget (c.f. Appendix 1).

For the analyses and interpretation of the position data, various software tools are available, e.g. R-package "recurse" which can be accessed through the following link: https://cran.r-project.org/web/packages/recurse/vignettes/recurse.html (Bracis et al 2018, Bracis 2019).

4 Acknowledgements

The production of this document was financially supported by the Swedish EPA and by in-kind support from the organisations of the co-authors. The authors thank Dr. Rachel Taylor, BTO, for comments and suggestions.

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Basic information about the distribution, ecology and behaviour of the EC is available in handbooks, e.g. Handbook of the birds of Europe, the Middle East and North Africa: Vol. 3 Waders to Gulls (Cramp and Simmons 1983), in national breeding bird atlases and on national and international websites (e.g. https://www.iucnredlist.org). Please note that some of the knowledge presented in these sources may be neither fully up-to-date nor scientifically evaluated.

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Appendix 1

GPS technology for EC studies

If your project has the capacity to use GPS technology, we advise you to carefully screen the market for the latest (reliable) models. Nowadays, solar powered units are standard, but there are still battery-only systems on the market. Unless you have strong reason to choose battery-only powered units, we recommend avoiding them.

The market for GPS tags is volatile and models and brands come and go. Make sure to prepare a well-informed list of specifications/requirements before you buy. Don't forget to include the costs for catching and data-transfer in your budget, because in the long run, those costs tend to be higher than the cost for the tags alone. Delivery time is also an important issue. Catching EC is often time-sensitive (i.e. can only be done at certain times, e.g. during incubation) and if the GPS units were not delivered in time, a full year of research may get lost. Suppliers of GPS units are usually unwilling to put strict delivery deadlines and related penalties in a contract. You can (a) take note of the experiences of others that have bought from the different suppliers, (b) try to put pressure on the suppliers or (c) accept and be prepared to be left empty handed.

Access and ownership of the position data is another important issue. It may be noble to make all the data freely available, but if you do, you may find that others have used your data in a publication without giving you any credit. You may not even like the message brought forward by their publication.

If free access is linked to data storage beyond your control (and responsibility), you may even discover your data vanished without a trace. We suggest you take the value of your data very seriously. Make and implement a good plan for how the data is stored, who has access to it and who has ownership and responsibility. If your GPS-tracking project includes other stakeholders: write a good contract!

Depending on the objectives of your study, focus can be on intensive sampling over a short period (e.g. a breeding season), a long one (multiple years) or both. In tag design, there is a trade-off between sampling rate (number of positions per unit time) and power supply. Solar panels can power GPS units for several years, but usually not at very high sampling rates for longer times, especially not during poor sunlight condition (as during winter months). Modern units can be programmed and steered (e.g. through SMS messages) to shift sampling rates, but this functionality comes at power costs and is not always flawless. Check the specifications of available models carefully before you buy.

Currently, most GPS tags are fitted on adults, but we can expect the numbers of tags on chicks to increase when tag-weights decrease (c.f. Chapters 1.3.11 and 3.2.4). The advantage of tagging chicks is that their age and origin are known, while for adults, this may not always be the case.

Catching and tagging are invasive procedures and should only be used if the scientific output is large enough to motivate the negative impact on the individual birds. From this perspective, it is highly questionable to tag individuals that are unlikely to deliver a rich output of data, e.g. chicks under high risk of predation. For the welfare of the birds, the lighter the GPS-tag, the better. The way the GPS-tag is attached is also vital for the welfare of the bird and thus, the quality of your research. Ask experienced teams for advice and training.

Appendix 2

Floatation method for estimating hatching date

The van Paassen apparatus

Aad van Paassen & colleagues in the Netherlands developed the "van Paassen apparatus" for the prediction of hatching dates. The method builds on the fact that eggs lose weight during incubation while their volume remains the same. Most of this empty volume sits in the blunt end of the egg and thus, eggs float in water with their blunt end higher and higher up. The predictive measurement is taken in one of two different ways (below). The result is then compared with tables or diagrams based on measurements of conspecific eggs with known time to hatching.

During the first c. two weeks of incubation, EC eggs remain submerged (Fig. A2.1) and you use the inclination (the angle between the top-to-bottom axis of the egg and the horizontal plane) as the measurement of interest. You can either use a graded drawing tool (Fig. A2.2) or the inclination-measuring tool in your smartphone. Make sure you measure the angle of the central axis of the egg, nothing else. An example of a diagram with which you can estimate expected hatching time is in Fig. A2.3.

! Please note that the water in the floatation chamber should neither significantly **cool** nor **over-heat** the egg. Hand-warm water is preferred. After the floatation testing, each eggs should be wiped dry before returning it into the nest.

During the last c. two weeks of incubation, a part of the egg sticks above the water surface. Now you measure how much the egg reaches above the water table with a simple ruler. Make sure to measure the height above the water table inside the container, not the level of water "crawling" up against the wall of the container. Fig. A2.4 shows an example of how this height measurement can be used to predict hatching time.

Expect an accuracy of ± 4 days. Depending on the objectives of your study, you may need complementary information (e.g. from repeated nest visits) to document the true time of hatching. Here you may have to recognize that hatching takes some time and that not all eggs in a nest hatch exactly at the same moment.

You can easily create your own comparative diagrams over the course of your study from data on the duration between the van Paassen measurement and hatching. Your own diagrams will probably be more accurate for your environment and your EC population.

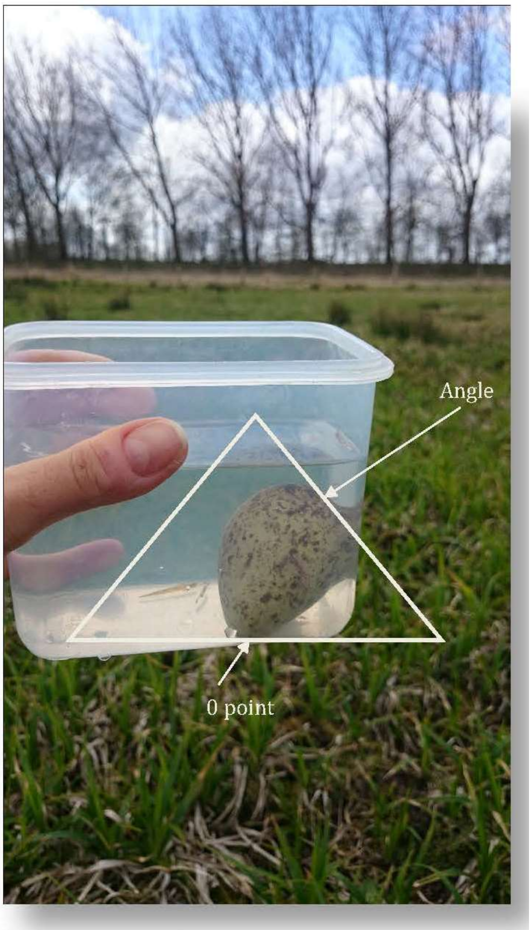

Figure A2.1. Example of a floating chamber. Photo: Natalie Meyer.

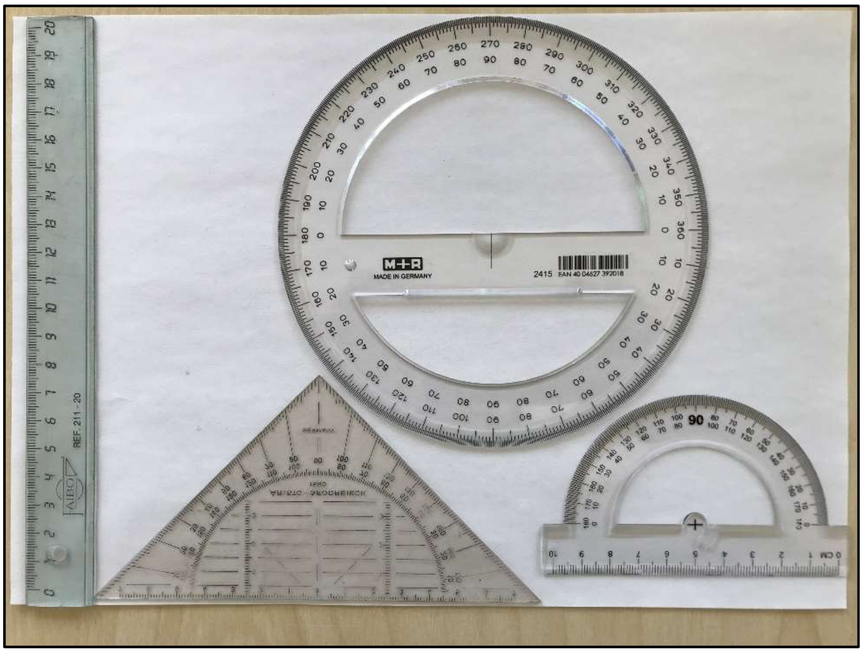

Figure A2.2. Example of measuring tools for floatation testing. Photo: Adriaan de Jong.

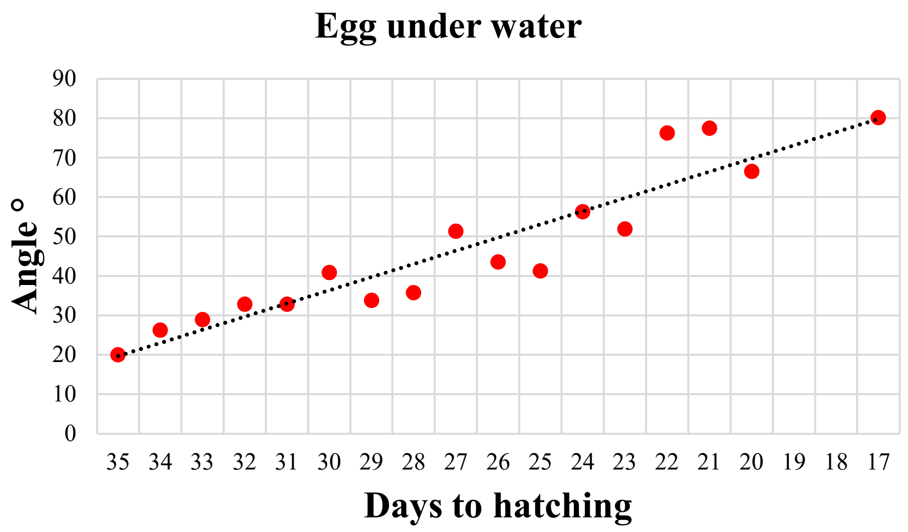

Figure A2.3. Numeric relationship between the angle of the egg in the floatation chamber and the estimated numbers of days to hatching for eggs remaining under the water surface during testing. Data by Natalie Meyer.

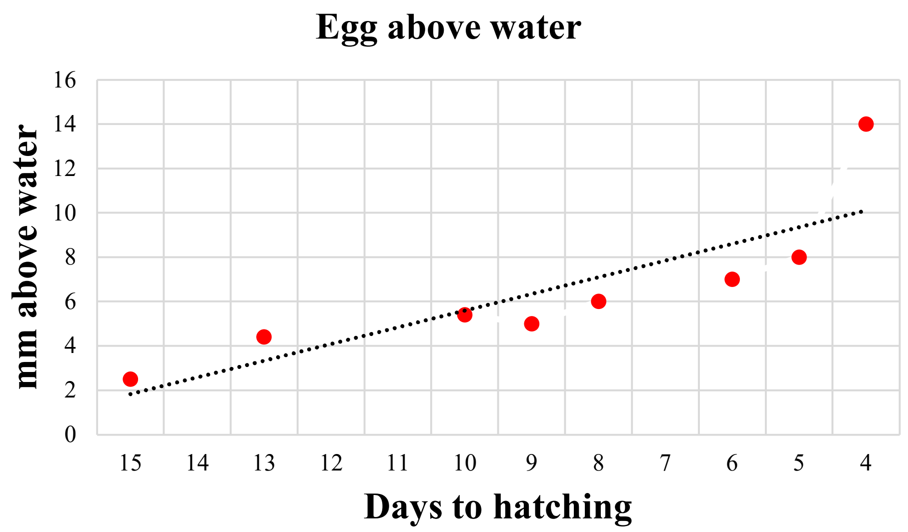

Figure A2.4. Numeric relationship between the height (mm) of the egg above the water surface in the floatation chamber and the estimated numbers of days to hatching for eggs floating above the water surface during testing. Data by Natalie Meyer.

Appendix 3

The “calliper-method” for estimating hatching data

Like the floatation method (Appendix 2), this method builds on the fact that eggs lose weight after laying while their size and volume remain the same. Here the volume is estimated from measurements of the length and the width/breadth of the egg in a species-specific formula. The length is measured along the length axis of the egg at its maximum length. The width is measured at the egg’s widest point (“belly”) and it is wise to make two measurements at 90 degree angle from each other and add these two values in the formula. The density of the egg is then calculated from weight/volume. Finally, the outcome of this division is used in a concluding formula that predicts the days left to hatching.

! Please note that the tips of the calliper (between which the egg is to be measured) are potentially harmful to the egg. Too much local pressure on the egg can easily break the egg-shell. We strongly suggest you avoid measuring by “squeezing” the egg between the fingers of the calliper. Instead, you should fix one of the fingers (probably the one nearest to the handle and scale) and then gradually increase the opening between the fingers while you gently slide the free finger over the surface of the egg until it reaches the widest point. By doing so (and some practice, e.g. on regular hen’s eggs) you can avoid any excessive pressure on the eggs.

For this method you need a good calliper and a decent weighing device. Electronic callipers are easily available nowadays and they typically measure to the nearest 0.01 mm. At this level of precision, calibration and correct onset of the calliper to the egg surfaces are vital. Make sure to follow the maker’s instructions carefully and we suggest you train and test your measuring skills on commercial hen’s eggs (which are roughly the same size as EC eggs). Electronic weighing devices are also readily available (most bird ringers use them), but most of them are not made for rough fieldwork, mainly because they are sensitive to the stability and inclination of the surface they stand on. Instead, you may want to use a traditional string balance (e.g. Pesola 100 g). EC eggs are appr. 70 mm long, 50 mm wide, and weigh c. 70 gram.

For the predictive formula, we suggest the one in Grant (1996):

Days to hatching = -134.83 + 0.32(weight / (length x width1 x width2))

Where weight is in gram, and length and widths are in mm. Instead of two different widths, you can use the same width measurement twice.

This prediction underestimates the numbers of days to hatching for measurements taken early during incubation and overestimates them during the later parts. For this, Grant (1996) presents an additional correction formula:

Corrected number of days = - 5.93 + 0.24 (Originally predicted number of days)

You can easily combine these two formula and store the result in your smartphone or computer for instant access in the field. This combined calculation comes with an estimated accuracy of ± 2 days (Grant 1996). Other references to calculations of predicted hatching date from egg measurements are in e.g. Hoyt (1979), Green (1984) and Galbraith & Green (1985).

Appendix 4

Thermo buttons for monitoring incubation and hatching

Thermo button are uniquely coded, round metal cases (similar in shape of flat lithium batteries) containing a thermometer, a timer and memory (Figure A5.1). After setting the timer, these loggers can be placed under a nest. After retrieval and downloading, the time series of temperature data show how the temperature changed.

Incubation bouts are shown by short cooling periods when the adult stand up to stretch their legs and turn the eggs or when parents shift watches. Longer cooling periods followed by a temperature rebound are indicative of disturbance or partial predation.

A permanent drop in temperature indicates either a predation event or hatching. Typically, complete predation and nest abandonment creates a steep permanent decline of temperature, while hatching is shown by a longer, jerky trend. The time of day of predation events hint on the type of predator; with avian predators assumed to be confined to daylight hours and mammalian predators mainly active between dusk and dawn. Please note that EC also breed in high-latitude environments where nights are light during the breeding season.

Thermo buttons are available from various sources and in different classes for temperature range and memory size. The units are cheap (a couple of Euros a piece), but you need a USB-dongle connected to a computer for initiation and downloading. Cheaper versions are water-resistant but not water-tight and may require sealing or additional casing. Stearin, paraffin or nail-polish can be used for sealing.

Figure A4.1. Standard thermo button compared to a CR2032 Litium battery.

Appendix 5

Camera surveillance for EC studies

If visiting nests causes undesirable disturbance for the breeding adults or takes too much of your time, you can use cameras to collect information about the nest while you are away. Nest cameras can provide information on hatching success, timing of failure, predator species, etc. There is a large variety of wildlife cameras[10] available on the market, in a wide range of prices. It is also possible to build customized units, e.g. based on Raspberry Pi micro-computers. Customized systems can include more functions than visual surveillance alone, e.g. radio frequency identification (RFID) of tagged adults, temperature sensors and microphones.

The welfare of the birds and the security of their nest must be the main focus in the decision to put up cameras or not (see also Chapters 1.2.5 and 1.3.7). If your camera technology requires modification of the environment near the nest (e.g. clipping or removal of vegetation), this aspect must also be taken into consideration. Any significant influence of the camera on the behaviour of the birds or the fate of the nest will compromise your study. When in doubt, do not put out cameras.

Key technical features to consider are power supply, data storage, focal distances and resolution, and, last but not least, type of footage to record. Commercial cameras are usually battery-powered and use standard AA and/or AAA type batteries. How long those last depends on the camera brand, the recording settings and environmental conditions, mainly temperature. You should always choose to stay away from the specified performance limits, because losing a few hours (or even minutes) recording time can make you miss vital events and thus, spoil your monitoring plan. Supplementary power from car/motorcycle batteries may be an option, but requires some basic skills in electrical engineering.

Recent developments in memory chip technology have virtually removed all former limitations for still-pictures and intermittent video. For permanent video (even at low and medium resolution), storage capacity is still a major issue, though. Although many odd “standards” have vanished from the memory card market, you still need to make sure the memory chip matches the requirements of your camera. When deciding which camera to buy, this “matching” should probably be reversed = make sure the camera matches current mainstream memory card standards. Please notify that even the file allocation systems and storage speed must match. This is particularly true for high performance, high capacity memory cards = the ones you would like to use for advanced applications. Similar to power supply, avoid to push your memory system to the specified limits. These may be overly optimistic and you don’t want to miss important moments.

Most modern cameras have adjustable focus setting. Depending on the aim of your project and the mounting options, focus settings can turn the quality of your footage from barely useful to stunning. Similarly, the resolution of the sensor chip will have a large impact on the quality of

[10] These cameras come under several different names, e.g “trail cams” or “hunt cams”. Professional surveillance camera systems for streets or buildings are not covered by this text, because they require more support functions (grid power, video recorder, etc.) and usually licenses. They are also significantly more expensive. Their future potential lies in high-resolution, non-intermittent video recording from long distances, but only under favourable technical conditions.

the footage. With memory card storage capacity issues largely removed, the speed and rules for the interplay between the camera and the memory chip are the important factors, e.g. a slow memory card in a fast camera will limit your image quality options.

The type of footage you want to record is vital for the choice of the camera and its settings. In its simplest form, wildlife cameras record still-pictures or video bouts at pre-set intervals. Anything happening during the intervals between the recordings passes unnoticed. Obviously, the shorter these intervals, the smaller the chance to miss important moments. To remedy this, many wildlife cameras use motion or motion/temperature triggering ("camera traps"). Here, the sensitivity of the trigger is vital. If the trigger responds to every move of a leaf or a straw of grass, the memory system will get swamped, the power supply drained and post-processing overloaded. Make sure to locate the "eyes" of the trigger system and arrange the mounting of the camera and the line of vision in front of the trigger system so that false positives (unnecessary triggers) and false negatives (missed events) are avoided. When the camera allows for variable duration of the triggered video bouts, we suggest you apply a generous setting (several minutes if possible). Storage capacity can easily be accommodated for these longer video bouts (given unnecessary triggers are avoided), and you don't want to miss e.g. the full handling behaviour of the predator. The intervals between trigger events (when the trigger system is inactive) isn't equally important. Here, longer periods may very well be acceptable.

Many commercial cameras also offer "night vision", i.e. the ability to see in the dark. This term is a bit confusing, because there are many technical aspect that vary. Most of all, it's the sensitivity for the spectral range of infrared light that varies. Most cameras use near-infrared light while far-infrared units (used in professional/military applications) are rare. Many night vision cameras use infrared light diodes to lighten up the surrounding, but the range and intensity of this lighting varies significantly. Within the framework of these guidelines, we cannot provide comprehensive, up-to-date information on all these technical aspects. Instead, we suggest you contact a trustworthy source or make your own experiments. For middle-of-the road applications, many standard systems are probably good enough, but if your ambitions are high, you need to be sure to choose the right equipment with optimal settings.

Cameras with internet connection have become increasingly available. The internet connection comes at a heavy power cost (reduced battery life), but in school projects, visitor centres, etc., live documentation of EC's family-life may be an effective tool for conservation through awareness raising.

The mounting of the camera next to the nest is an important factor. Most cameras need some sort of support structure, typically a stick or a small pole. The camera can also be hidden in a blind to mask its shape in (semi)flat terrain. The camera-lens must be high enough above the ground to provide a proper view on the nest and sight-blocking (growing!) vegetation is adverse. The distance from the camera to the nest should be as large as possible, but off-the-shelf wildlife cameras will probably need be placed 0.5-2 m from the nest. Larger distances under the requirement of a visible nest-cup translate into larger poles, which is a disadvantage for visibility of the camera unit (risk for theft) and possibly increased egg predation. You have to carefully weigh all the factors to come to the best solution for your project, but the safety of the nest and eggs comes first.

After placing the camera close to a nest (avoid destruction of the nest environment as much as possible!), watch carefully (from a blind or a car) to make sure the birds return to their nest. If the camera disturbs too much, birds might abandon their nest. If birds are disturbed, either try placing the camera farther away from the nest or remove it completely. Respect that some individuals are more sensitive than others.

The wealth of footage on the memory cards needs to be viewed and interpreted. For some research questions (e.g. When was the nest predated and by what predator species?), this post-processing is easy and quick, but for others (e.g. documentation of incubation bouts and disturbances) it may be challenging. Commercial and freeware solutions are available to wade through large amounts of photo and video footage, increasingly involving AI/machine learning (e.g. Tabak et al. 2019).

PS. *Camera technology is developing fast, and parts of this Appendix may become obsolete overnight due to technical or economical breakthroughs. Make sure to check up on these latest developments before you make a major investment in surveillance infrastructure for your EC project.*

Image A5.1 A trail camera used for survey work in Germany. Photo: Michael-Otto-Institut im NABU.

Photo A5.2. Images from cameras showing a racoon dog approaching a nest. Photo: Michael-Otto-Institut im NABU

Photo A5.2. Image from cameras showing a red fox approaching a nest. Photo: Michael-Otto-Institut im NABU.

Appendix 6. Extension program for studies of EC nests

Studies based on finding and monitoring EC nests require a significant amount of effort. They also disturb the parent birds and may even augment predation risk. Here we present four ways to increase the scientific outcome of nest studies without creating additional stress or risk.

Spatial analysis of nest fates
GPS and GIS[11] technologies are readily available these days. We suggest you register the coordinates of the nest site (preferably in a global coordinate system, e.g. WSG84) and link this information to your documentation of nest fate. In case you are familiar with spatial analysis (e.g. in freeware Q-GIS), you can analyse the spatial distribution of successful vs. failed nest sites etc. If this is beyond the scope of your project, please make these spatially explicit data available to others.

Collect shed feathers
Incubating EC regularly shed down and small body feathers. Small numbers of larger feathers can also be found (Fig. A6.1). When you visit the nest, you can easily collect those feathers. Place them in a small paper bag or envelope on which you write date, site (coordinates) and your name. Store dry in room temperature. Vacuum-seal your feather bags if possible, but do not forget to add some silica gel. Any moisture inside the plastic bag will eventually accumulate at the coldest wall and that could be enough water to trigger microbial decay. Feathers are a good source of DNA and can be used for stable isotope analyses. In the future, more types of analyses are likely to become available.

Figure A6.1. EC nest with shed feathers. Photo: Harry Ewing.

[11] GIS stands for Geographical Information Systems.

Collect eggshell remains

After hatching, large eggshell remains are left in or near the nest. Under normal conditions, the remains of individual eggs are easily recognizable and you can collect them individually. In particular, the membranes are good sources of DNA for several days after hatching[12]. In case you have access to forensic skills and techniques, use those, but picking the eggshells up with your bare hands and storing them in appropriate containers works fine for many applications. Foldable papier-mâché containers for commercial hen's eggs[13] work fine (Fig. A6.2). No plastic bags, because these can easily lead to condensation against the inner surface and thus, microbial growth. For bug-safe storage: seal the egg-container together with silica gel in a paper bag/envelope inside a food-sealer bag. Do not try to vacuum-seal the egg-container, because this will crush the container and its contents. You can store the sealed unit in room temperature.

In addition to DNA, your samples can also be used for stable isotope analyses, eggshell thickness measurements and more.

Figure A6.2. Egg remains can be stored in regular hen's egg container and sealed in plastic foil together with silica gel. Photo: Adriaan de Jong.

[12] In contrast to mammalian blood cells, avian blood cells are a rich source of mitochondrial and nucleotide DNA.

[13] EC eggs are about the same size of hen's eggs, but their pointed shape makes them longer than normal sized hen's eggs. If you want to store whole EC eggs, you need larger containers, e.g. containers for goose eggs.

Collect predated nests

Predators leave DNA traces when they rob a nest. CSI-style, you can collect nest cup material for predator identification. Unlike in collecting eggshell remains, you need to reduce contamination risk by using disposable gloves and sterilized containers. This is because the amount and the quality of the predator's DNA will probably be very low and the adequate molecular methods highly sensitive to contaminations (e.g. from your dog's DNA). Vacuum-sealed nest material (+ silica gel) can be stored in room temperature for a long time.

Appendix 7

Nest sites and the appearence of eggs vary

Figure A7.1

Figure A7.2

Figure A7.3.

Figure A7.4.

Figures A7. 1-4. Photo: Natalie Meyer.

Figure A7.5.

Figure A7.6.

Figure A7.7.

Figure A7.8.

Figures A7. 5-8. Photo: Harry Ewing.

Figure A7.9.

Figure A7.10.

Figure A7.11.

Figures A7. 9-11. Photo: Tatiana Sviridova.

Appendix 8

Nests with aberrant eggs

Figure A8.1. Photo: Natalie Meyer.

Figure A8.2. Photo: Gerrit Gerritsen.

Figure A8.3. Photo: Adriaan de Jong.

Figure A8.4. Photo: Natalie Meyer.