How can we improve citizen science based bird monitoring in Denmark?

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(Med et dansk resumé: Hvordan kan vi forbedre fugleovervågningen i Danmark?)

Abstract Citizen science is an indispensable means of obtaining the information necessary for maintaining bird monitoring programmes. The aim of this paper is to inspire creative thought and discussion among the ornithological community, scientists and decision makers in Denmark to improve the quality and extent of breeding bird monitoring. We review the status of monitoring programmes in Denmark and use this information as a basis for discussing how we could best improve citizen science based bird monitoring programmes in the future. We undertake a gap analysis to establish some immediate priority areas for attention. In particular, we argue for initiating programmes that deliver information on demography parameters such as survival, reproduction, immigration and emigration to better interpret overall trends in abundance. We suggest combining data from different monitoring programmes to develop the possibilities for the integrated analyses of population counts and demographic data within population models, which will contribute to more effective management and conservation in the future.

Introduction

There is a long tradition of monitoring bird abundance and distribution in Denmark and neighbouring countries, much of which is highly dependent on the commitment, interest and willingness of volunteer participation. This commentary describes the extent of citizen science based breeding bird monitoring and builds on past achievements in Denmark. The aim is to stimulate debate about how better to maintain and improve this major contribution to future avian research and conservation in the country. We conclude by undertaking a gap analysis to establish immediate priority areas for the future.

A major objective of this exercise is to quantify the degree to which all Danish breeding species are adequately covered by existing monitoring programmes and thereby establish which species suffer inadequate coverage.

Citizen science has been defined as "projects, where volunteers partner with scientists to answer real-world questions" (www.birds.cornell.eduwww.birds.cornell.edu). Such public participation now contributes heavily to environmental research and monitoring across the world, and is most successful where strong partnerships exist between amateurs and professionals, benefitting from their complementary roles (Greenwood 2007). Monitoring programmes focus on changes in state, and invariably compare measurements in time and place with subsequent re-measurements, as in the case of population monitoring, to detect a population trend (stable, decreasing or increasing) and rate of change (slowing or accelerating). The target may be a population of a single species, populations of numbers of species, or composition of selected ecosystems (Greene 2012).

Citizen science has become indispensable to nature conservation by providing extensive information on broad temporal and spatial scales. It is financially impossible to support professional networks to gather such coordinated avian data from very large numbers of sites on the scale currently provided by volunteer participation (Greenwood 2007). This environmental monitoring information is the bedrock for government decision-making processes, EU reporting and policy development as well as supporting policy development, prioritisation and work programmes, and providing direct evidence for supporting avian conservation, site management and hunting regulation (Bregnballe *et al.* 2007, Greenwood 2007).

Citizen science is an accepted means of data generation on bird population sizes and rate of change to contribute to fulfilling the requirements of national and international legislation and agreements (e.g. the European Union Birds and Habitats Directives and the Ramsar Convention e.g. based on 1% flyway population definition). Existing extensive volunteer networks coordinated by relatively few professionals, provide an indispensable capacity to perform surveys undertaken at a variety of spatial scales (from the site level to covering whole continents) driven by highly competent and motivated but ultimately volunteer participants (Dickinson *et al.* 2010). Further major contributions from citizen science come from projects initiated by individuals or groups of dedicated birdwatchers, who become species/habitat specialists. Such studies may result in scientific publications with or without the coordination or help of professionals (e.g. Thellesen 2017, Østergaard 2017) or provide the basis for further studies (e.g. Heldbjerg *et al.* 2017).

Citizen science in Denmark in the past

Long before the formal establishment of centres of learning, ordinary people were driven by curiosity to contribute to avian citizen science in Denmark, as elsewhere. Hans Christian Cornelius Mortensen made some of the earliest contributions to Danish avian citizen science, by marking Starlings *Sturnus vulgaris* to find out whether the same birds returned annually to nest boxes and where they travelled in winter (Preuss 1997). In 1960, DOF-Birdlife Denmark (Dansk Ornitologisk Forening (DOF)) organised a site-based survey of the most important bird areas, the first nationally coordinated Danish bird monitoring project (Ferdinand 1971), which was repeated in 1978-81, 1993-96 and 2003-13 (Flensted & Vikstrøm 2006, Vikstrøm *et al.* 2015). From the mid-1960s to mid-1970s, various DOF volunteer groups undertook surveys of different bird groups (e.g. rare species, raptors and waders; see Møller 2006) and the first national monitoring of staging and wintering waterbirds was undertaken by professionals (undertaking aerial surveys from aircraft) while large numbers of volunteers conducted land-based counts (Joensen 1974). The national survey of waterbirds was repeated in 1987-1989 (Laursen *et al.* 1997) and irregularly thereafter, up until 2000 when regular national waterbird counts were introduced (e.g. Petersen *et al.* 2006) – from 2004 as part of the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA; Holm *et al.* 2016) – with a midwinter survey every three winters and moult surveys every six summers.

The first DOF atlas mapped the distribution of all Danish breeding birds (undertaken in 1971-1974 and involving 745 volunteers; Dybbro 1976), while a second (1993-1996, involving 750 participants) also attempted to estimate relative densities of common breeding bird species (Grell 1998). A survey to determine species assemblages of breeding birds in small rural biotopes in Denmark followed (Meltofte *et al.* 2009) and in May 2002, the Danish national bird reporting portal DOFbasen went online (www.dofbasen.dk; Nyegaard *et al.* 2012) to facilitate online reporting of all bird observations from anywhere in Denmark throughout the year.

DOF also coordinated volunteer observers to undertake timed point counts in the field to contribute to an annual assessment of the relative abundance of common birds in Denmark ('Common Birds Monitoring', CBM). This programme was initiated in winter 1975-1976 for wintering birds and in 1976 for breeding birds (Møller 2006) and these are among the oldest European bird monitoring programmes (Heldbjerg *et al.* 2015) which have generated common bird population indices for over 40 years and supported research projects (e.g. Fox 2004, Heldbjerg *et al.* 2016, Lehikoinen *et al.* 2016).

Intensive site-based professional monitoring at field stations established by government departments between the 1920s and 1980s covered some of the most important breeding and staging areas for waterbirds in Denmark (at Christiansø, Vejlerne, Tipperne, Vorsø and Langli) and breeding seabirds on Christiansø (Lyngs 2006), but all these stations were closed or significantly reduced in the 1990s due to withdrawal of government funds. Despite invaluable and irreplaceable annually reported results, the major financial costs of supporting these significant programmes failed to guarantee their continuity. The lesson to be learned here might be that very ambitious, costly professional programmes may suffer higher failure risk, compared to the current apparent robustness and continuity of simpler but successful citizen science surveys.

Present citizen science in Denmark

The Danish Ministry of Environment and Food (MFVM) has obligations under EU legislation and international conventions to report on the status of species and habitats, including birds. Denmark has initiated systematic monitoring of habitats and species included in the annexes of the Habitats and Birds Directives through the creation of NOVANA (Holm *et al.* 2016), which aims to monitor abundance and distribution of breeding birds and regularly occurring migratory bird species following Article 2 of the Birds Directive. Since 2004, mid-winter waterbird counts (MWC, as well as regular spring and autumn counts for selected species) are now also part of this monitoring framework after a period without such monitoring (Holm *et al.* 2016).

Currently, most Danish on-going bird monitoring projects are organised and run by DOF-Birdlife Denmark (DOFbasen, CBM) and/or the Department of Bioscience, Aarhus University (MWC). Some, such as NOVANA and CBM, are organised as partnerships, financed to varying degrees by MVFM. Other projects (e.g. the periodic Atlas programme, Atlas III, 2014-2017; Tab. 1) are financed by the Aage V. Jensen Charity Foundation.

Monitoring species

Maintaining and elevating current levels of biodiversity in Denmark requires continued and improved monitoring of species and habitats to provide knowledge of the status of species and habitats and the effects of implemented local (i.e. site based) and national initiatives and action plans (Miljøstyrelsen *et al.* 2017). Species monitoring tracks changes in distribution and abundance, from the local up to the national and international levels, in order to differentiate local changes in distribution and abundance from patterns at the population flyway level, and to contribute to flyway population estimates.

Annual monitoring of abundance. Assessing changes in annual relative abundance of avian species derives from different monitoring programmes depending on species, for example, abundance, secretiveness and diurnal activity. Winter and breeding season CBM data are gathered by 300 volunteers to generate samples of relative abundance and contribute to the estimation and reporting of annual indices for 80-110 species (Moshøj *et al.* 2017). Scarce and rare breeding birds require focused, intense monitoring to generate national trends, which have been maintained since 1998 by DOF's DATSY project (Grell *et al.* 2004, Nyegaard *et al.* 2014; Tab. 1); the DATSY project connected birdwatchers with knowledge of rare breeding birds to provide estimates of abundance and assess changes in national population size. Initially funded by the Aage V. Jensen Charity Foundation (Flensted & Vikstrøm 2006), this project was later part of the agreement between DOF and MFVM (Nyegaard 2016), but since 2013, this group of birds has only been covered for some of those listed on Annex I of the Birds Directive and from 2018 only on sites designated for those species (Miljøstyrelsen *et al.* 2017). If maintained, we can no longer produce reliable annual population estimates and trends for any of these species except White-tailed Eagle *Haliaeetus albicilla*, Montagu's Harrier *Circus pygargus*, Golden Eagle *Aquila chrysaetos* and Osprey *Pandion haliaetus* which are now covered by existing specific citizen science monitoring programmes coordinated by DOF.

NOVANA monitors the status and trends in distribution and abundance of Annex I species (Miljøstyrelsen *et al.* 2017). With the exception of annually monitored breeding Cormorant *Phalacrocorax carbo* (Bregnballe & Nitschke 2017), this programme has a rolling six year cycle, monitoring any given species every two or three years. Thirty-six Annex I breeding bird species are surveyed as part of the 'Intensive 1 monitoring of breeding birds' programme largely undertaken by staff at the Environmental Protection Agency (EPA) and consultants (Appendix 1; Miljøstyrelsen *et al.* 2017).

The remaining Annex I breeding birds comprise part of the 'Intensive 2 monitoring of breeding birds' programme, and these birds are monitored based on quality assured data derived from DOF/DOFbasen, i.e. entirely based on citizen science records (Holm & Søgaard 2017). They are Black Stork *Ciconia nigra*, White Stork *Ciconia ciconia*, Mediterranean Gull *Larus melanocephalus*, Osprey, Golden Eagle, Montagu's Harrier, White-tailed Eagle, Peregrine Falcon *Falco peregrinus*, Boreal Owl *Aegolius funereus,* Short-eared Owl *Asio flammeus*, and Tawny Pipit *Anthus campestris* (Appendix 1).

Distribution. Atlas surveys have so far described Danish breeding bird distributions every c. 20 years, and the recently completed 3rd Breeding Bird Atlas has generated comparable data using more or less identical basic methods as the two previous atlases. A new initiative, using line transects with distance bands to estimate both relative and absolute winter and breeding bird densities, is also expected to provide improved national population estimates for c. 45 breeding and 30 wintering species (Levinsky 2016).

DOFbasen now hosts vast numbers of casual (i.e. unsystematically compiled) avian records. Numbers of sites, observers and records have increased every year until 2016, stabilizing in 2017-2018 at c. 1.5 million records contributed by c. 2400 observers from c. 14000 sites annually. The mostly unsystematic nature of the data restricts their use and interpretation, although complete lists of timed visits are encouraged and are far more valuable than casual incomplete records (Kamp *et*

Tab. 1. Overview of the most significant citizen science national monitoring projects for birds undertaken in Denmark 1960-2017.
Oversigt over de mest betydningsfulde, frivilligt baserede, nationale fugleovervågningsprojekter i Danmark 1960-2017.

Project ***Projekt***	**First year** ***Første år***	**Last year** ***Sidste år***	**Publication** ***Publikation***
(No English title) *Større danske fuglelokaliteter*	1960	1977	Ferdinand 1971, 1980
Staging and wintering waterfowl in Denmark *Midvintertællinger*	1965	1973	Joensen 1974
Atlas I (no English title) *De danske ynglefugles udbredelse*	1971	1974	Dybbro 1976
Common Bird Monitoring, winter *Punkttællinger, vinter*	1975/76	Ongoing	Moshøj *et al.* 2017
Common Bird Monitoring, breeding *Punkttællinger, ynglefugle*	1976	Ongoing	Moshøj *et al.* 2017
Rare and threatened breeding birds in Denmark	1976	1991	Sørensen 1995
(No English title) *Status for danske fuglelokaliteter*	1978	1981	Dybbro 1985
Staging and wintering waterbirds in Denmark *Midvintertællinger*	1987	1989	Laursen *et al.* 1997
Atlas II (no English title) *Fuglenes Danmark*	1993	1996	Grell 1998
(No English title) *Fuglenes Danmark: Fuglelokaliteterne i Nordjyllands (etc.) Amt*	1993	1996	Various authors 1997-1999
Rare and threatened breeding birds in Denmark *DATSY – Truede og sjældne ynglefugle*	1998	Ongoing	Grell *et al.* 2004, Nyegaard *et al.* 2014
DOFbasen (www.dofbasen.dk) *www.dofbasen.dk*	2002	Ongoing	Nyegaard *et al.* 2012
IBA Caretaker project *Status og udviklingstendenser for Danmarks internationalt vigtige fugleområder*	2003	2013	Vikstrøm *et al.* 2015
Mid-winter counts *Midvintertællinger*	2004	Ongoing	Holm *et al.* 2016
Birds in Danish gardens in winter *Den Store Vinterfugletælling*	2007	2011	Meltofte & Larsen 2015
Atlas III *Atlas III*	2014	2017	Levinsky 2016

al. 2016). Nevertheless, the vast number of records accumulated provides another valuable source of information on year-round avian abundance and distribution.

Monitoring sites

International legislation obliges Denmark to monitor species in Natura 2000 sites. The Danish EPA is responsible for reporting the status and trends at the Natura 2000 sites to the EU as part of the EU bird reporting every six years. Municipalities, large landowners like the Aage V. Jensen Charity Foundation and NGOs such as the Bird Protection Fund also share an interest in tracking changes in site biodiversity by monitoring different taxa. Site-based knowledge also contributes to understanding whether species declines reflect local site-quality degradation or population declines at the flyway level. Local site monitoring can also show whether site management has beneficial effects on restoring numbers. As shown below, cohesive integrated site-based monitoring forms the basis for contributing to management and conservation from site up to flyway levels (Kirby *et al.* 2008).

DOF's Important Bird Area (IBA) 'Caretaker' project almost exclusively used citizen science monitoring to provide detailed knowledge on avian abundance at the most important bird sites in Denmark, primarily focused on species for which sites were designated under the Birds Directive. The Caretaker project was funded by the Aage V. Jensen Charity Foundation during 2003-2013 (Vikstrøm *et al.* 2015) but no funding or dedicated platform is currently available for its continuation. Currently, 130 IBAs regularly support more than 1% of the flyway population of a species or are judged by other criteria to be of international importance to one or more species of breeding, staging or migrating birds (Vikstrøm *et al.* 2015). DOF 'caretakers' are sometimes involved in actively managing the sites to benefit nature conservation interests and enhance visitor experiences. They also help in communicating the value of such sites by leading field trips, maintaining websites etc. Finally, 'caretakers' support government bodies, the wider community and landowners to protect sites by raising awareness of the environmental pressures acting upon and damaging the sites (Vikstrøm *et al.* 2015).

Parameters relevant for distribution and abundance

Population parameters

In order to establish changes over time, the basic objectives for monitoring any species are to establish their distribution (where is a given species present?), phenology (when is a species at a given site?) and abundance (how many are there?). Distributional information comes mainly from atlas surveys and abundance from CBM and MWC, while DOFbasen contributes phenology.

Understanding factors affecting distribution and abundance. Many species show considerable changes in distribution and/or abundance due to factors such as climate changes, land use changes and other human effects (e.g. hunting or disturbance), as well as changes in predation or competition due to changes in other species' populations. Development of appropriate management strategies relies on an understanding of whether changes relate to reduced reproductive success or survival, because causal factors may be manifest at different times in the annual cycle and, potentially, in different geographical areas. This provides a powerful motivation for tracking demographic measures simultaneously with population trajectories, especially in an adaptive management framework (Schaub & Abadi 2011).

Demographic parameters

In closed populations, changes in abundance and/or distribution arise from changes in demography, i.e. survival and reproductive success. Changes in survival rate will inevitably potentially have consequences for the population size, especially in long-lived species that are more susceptible to relatively small changes in adult survival. In contrast, many small-bodied birds are short-lived, so annual changes in population size are highly dependent on the relative contribution from large numbers of fledglings. Such populations need to produce sufficient young to replace annual numbers dying, otherwise the population declines (Newton 2013).

Greater insights into processes limiting reproductive success may be derived from understanding the steps faced by birds along the route to successfully producing sufficient young to the stage of independence (Newton 2013). These include: age of first breeding and breeding propensity throughout adult life, the number of eggs laid, the proportion of the eggs that hatch, the number of hatchlings that fledge, and the number of clutches laid per season (the latter requiring colour marked individuals to confirm the number of clutches per female). Such parameters can be derived for the commoner species through nest recording schemes. Citizen science networks can be highly effective at generating such kinds of data, as long as they are given proper encouragement and training to observers to ensure minimum levels of disturbance associated with such data gathering activities (Crick *et al.* 2003).

As a nest box breeder, the Starling is a species that lends itself to breeding success studies. Photo: Henning Heldbjerg.
Stæren yngler gerne i fuglekasser og er dermed en af de arter, hvor det er let og uproblematisk at undersøge ungeproduktionen.

Even outside the breeding season, citizen science monitoring may generate data to estimate the annual ratio between young and adult birds several thousand kilometres away from the breeding grounds (e.g. Robinson *et al*. 2005). The annual production can be assessed for some species, e.g. Dark-bellied Brent Geese *Branta bernicla bernicla* in winter, to identify the often complex and interacting drivers of change in reproductive success linked to Arctic lemming and predator populations (Nolet *et al.* 2013).

Raw data generated by citizen science networks still require scientists to analyse how temporal changes in avian demographic parameters affect changes in population growth rates. Population models can help reveal to what degree different parameters such as climate change, changes in land use, human and biological effects affect avian abundance (e.g. Bowler *et al.* 2018) and how demographic factors contribute to annual rates of change in population size, including immigration/emigration rates at the site level (Weegman *et al.* 2016). Such insights can help us understand where and when to look for limiting and regulating environmental factors and represent a powerful tool for guiding policy and management actions.

Other methods to describe demographic parameters
Bird ringing recoveries enlighten us about migration (e.g. Lyngs 2003, Bønløkke *et al.* 2006, Hammer *et al.* 2014) but also play a vital role in identifying changes in annual production, survival and dispersal - demographic parameters contributing to population change.

Constant Effort Site (CES) ringing is an important example of how citizen scientists, i.e. ringers, can derive spatially explicit and structured data that helps us understand population processes. CES contributes to estimation of the annual production of a given species without knowing the number of reproducing females and, over time, generates local survival estimates (Robinson *et al.* 2009).

CES started in Denmark in 2004 and by 2015 consisted of five contributing ringing sites (Knudsen 2015, Ettrup 2016, Ettrup & Madsen 2017). The Retrapping Adults for Survival project (RAS), launched by the BTO in the UK, was designed to estimate annual adult survival rates (as in the case of hirundines; Robinson *et al.* 2008) and has yet to be introduced in Denmark. Although the capture and marking of birds is restricted to qualified bird ringers, for many species (e.g. gulls and geese) the reading of conspicuous markers on birds in the field depends on networks of amateur enthusiasts, e.g. the long-term population study of wild Greylag Geese *Anser anser* in Copenhagen (Kampp & Preuss 2005). Traditional steel or aluminium leg rings fitted to birds bear a return address and a unique code, usually only readable if the bird is caught or found dead. Colour rings and other more conspicuous individual markers gives the opportunity to determine the identity of an individual at a distance with certainty without the need for recapture, thus making important contributions to survival and other studies.

Recent high-technology developments enabled the deployment of GPS-loggers on birds gather extremely detailed information on geographical positions, behaviour, flight altitude and speed, often with additional data, and are downloadable directly to a computer. Such devices provide new possibilities to study wildlife but are limited by the size/weight of the loggers relative to bird size, as well as equipment costs. Current cost and technical requirements restrict them to the realm of citizen science/professional partnerships (Heldbjerg *et al.* 2017).

Hunters also contribute uniquely valuable monitoring data by reporting of annual numbers of individuals bagged per species (raw data that are ultimately used to generate local, regional and national annual hunting harvest data). In Denmark, 'sustainable hunting' is restricted to species for which there is good scientific evidence that the population can withstand current levels of hunting pressure without diminishing population size, and is subject to legislative scientific review every four years (Bregnballe *et al.* 2007). Danish hunters have been required to report hunting bags for all quarry species since 1941, generating essential annual data on the size of the harvest for huntable species (Christensen *et al.* 2013). Although changes in these parameters may also potentially provide proxies for changes in population sizes, such relationships are complicated by changes in hunting season length, hunter effort and self-regulation in the face of increasingly rare prey (Kahlert *et al.* 2015). Hunters also voluntarily submit samples of wings of shot birds that enable the age and sex ratio of hunted birds to be determined (Christensen & Fox 2014). Starting in 1970 with a Woodcock *Scolopax rusticola* study (Clausager 1973), the wing survey was extended in 1980 to include ducks and waders, and later still to geese and gulls (Bioscience 2017a). The more than 13 000 wings contributed annually provide vital information on the annual variation in sex ratio and age ratio of different species, which is impossible to currently derive by other means (e.g. Christensen & Fox 2014).

Considerations for future citizen science on birds in Denmark

Bird populations may be limited at any time of the year and since migratory species only occur in Denmark at certain times of the year, it makes sense to treat the seasons separately. This is especially the case for many widely dispersed boreal and Arctic-nesting species that aggregate at staging and wintering areas where there is a rich supply of local ornithologists. For many such species, assessment of year-to-year fluctuations in annual abundance is only feasible outside of the breeding season to fulfil, for instance, requirements to monitor such populations under international laws, conventions and agreements.

Millions of migrating birds pass through Denmark every spring and autumn. Monitoring of the important sites for staging migrants is coordinated with respect to other parts of the EU Birds Directive (Article 4.2; Miljøstyrelsen *et al.* 2017). Many bird species also occur in Denmark in large numbers during winter, and for sedentary species winters offer an alternative source of monitoring data. Winter bird monitoring could involve thousands of citizen science observers in projects such as dedicated winter bird atlases or 'Feeder watch'. However, for the scope of this analysis, the discussion about the future activities in this paper is focused primarily upon considering citizen science based bird monitoring of Denmark's breeding birds.

A monitoring gap-analysis of breeding birds in Denmark

The breeding period is the period of the year with the most rapid change in population level. Within a short period the population changes from its annual low to its highest level and it is the only point in the annual cycle when population numbers increase. The movements of all species are limited by the nesting activities in this period; hence it is a crucial part of the year and an optimal time to monitor the size of the breeding populations. We present a framework for effective breeding bird monitoring, which aims to analyse how well we currently monitor changes in bird population abundance and distribution. Although this was undertaken by DOF's Scientific Committee in 2000 (Thorup *et al.* 2000), the challenge to review and update our needs remains just as relevant today.

Do we obtain adequate monitoring data on changes in annual population size in Denmark? This gap analysis covers all 227 species that have ever bred regularly in Denmark of which some were subsequently excluded (see more details in Appendix 1-3). In order to focus only on those which are 'Regular' breeding species at present, all 'Regionally extinct' species (9 species) and 'Occasional' breeding birds (24) were excluded, as were all introduced/invasive alien breeding species (4 species; described in Fox *et al.* 2015).

Since the last Danish Red List was published in 2009 (Bioscience 2017b), four species, Whooper Swan *Cygnus cygnus*, Mediterranean Gull, Golden Eagle and Boreal Owl have been added as recent regular breeding birds (Knud Flensted, pers. comm.). The status of each species has been updated until 2017, including records of last confirmed breeding, based on information from Dybbro (1978), Olsen (1992), Grell (1998), Nyegaard *et al.* (2014), Birdlife International (2015), unpublished information from DOFbasen and the Atlas programme (Appendix 1). This gives 190 regular breeding species for which we have Danish population size estimates, and 110 of these species are sufficiently abundant and detectable to allow estimation of breeding population indices with an acceptable degree of confidence from the CBM. The CBM generates an index of annual population size change with no direct relationship to the absolute Danish population size. In general, the more common a species is, the more precise the population index; however, for the purpose of this analysis, all species with a CBM index are included, independent of the degree of precision.

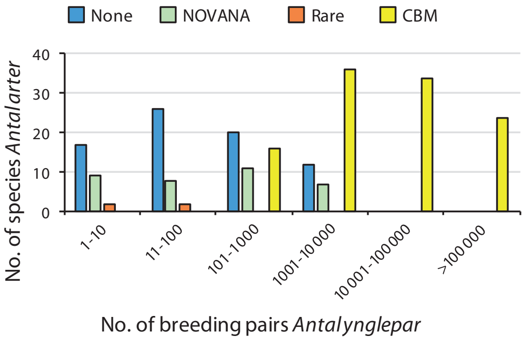

Fig. 1. Degree of monitoring coverage for 190 regular breeding bird species in Denmark. Well-covered rare species (Rare; 4 species) are indicated in orange, Common Bird Monitoring species (CBM; 110) in yellow and those species not currently monitored (None; 76) in blue. In addition, of the unmonitored species, those covered by the NOVANA programme every 2nd or 3rd year at sites where they are designated for is shown in light green (NOVANA; 35).
Graden af årlig overvågning af de 190 regelmæssige ynglefugle i Danmark. Sjældne arter (4) er vist med orange, punkttællings-arter (110) med gul og arter uden årlig national dækning (76) med blå farve. De af de ikke dækkede arter, der er delvist dækket af NOVANA (35) med tællinger hvert 2. eller 3. år på de områder, der er udpeget for arten, er vist med lys grøn farve.

At the other extreme of avian abundance, we also know with a high degree of accuracy the abundance of the few very rare breeding species, i.e. those that have received special attention through different projects (at present only four species) for which we are more or less able to determine the entire Danish population. The intermediate group of 76 regular breeding species (Appendix 2) are far more difficult to monitor, since they are too numerous to count individually and too scarce (or difficult) to monitor by traditional means. In fact, we are currently unable to monitor effectively most species in the one to 10 000 pair categories adequately (Fig. 1).

Within this group, 20 'Predictable' species effectively breed at the same sites year after year, compared to 56 'Unpredictable' species which may shift breeding sites between several sites of which we are not always aware. The 'Unpredictable' group comprises 11 nocturnal species and 45 diurnal, while the 'Predictable' group comprises only diurnal species. The 'Predictable' group are mostly coastal (11 species; 55% of the 20 predictable species) or inland wetland breeders (25%) (Tab. 2). A similar pattern is found in the 'Unpredictable' group (39% in wetland and 16% at the coast), but there is also an additional significant habitat group in forest (30%). Most 'Unpredictable' species (66%) are day-active and

Tab. 2. Number of regular breeding bird species in Denmark lacking annual monitoring, divided into different groups based on habitat categories, whether the breeding sites are predictable, the optimal monitoring period during the day and nesting habits (see also Fig. 1).
Fordeling af de regelmæssigt ynglende fuglearter i Danmark uden årlig overvågning, opdelt på naturtype, forudsigelighed af yngleplads, tidsrum for primære aktivitet og kolonialitet (se også Fig. 1).

Sites *Lokalitet*	**Time** *Tid*	**Nesting** *Kolonialitet*	**Wetland** *Vådområde*	**Forest** *Skov*	**Coast** *Kyst*	**Farmland** *Agerland/Eng*	**Heathland** *Hede*	**Urban** *By*	**Stream** *Å*	**SUM**
Predictable *Forudsigelig*	Night *Nat*		0	0	0	0	0	0	0	0
	Day *Dag*	Colonial *Koloni*	2	0	8	0	0	0	0	10
	-	Solitary *Enkeltvis*	3	0	3	0	3	1	0	10
SUM			**5**	**0**	**11**	**0**	**3**	**1**	**0**	**20**
Unpredictable *Uforudsigelig*	Night *Nat*		2	5	0	4	0	0	0	11
	Day *Dag*	Colonial *Koloni*	2	0	6	1	0	0	0	9
	-	Solitary *Enkeltvis*	18	12	3	0	1	1	1	36
SUM			**22**	**17**	**9**	**5**	**1**	**1**	**1**	**56**
Total *Total*			**27**	**17**	**20**	**5**	**4**	**2**	**1**	**76**

solitary nesting, requiring a large-scale sampling framework to adequately monitor this group. Twenty-one of the day-active solitarily nesting species (46%) occur on inland wetlands, which would therefore seem to represent a good starting point for adequately monitoring a broad suite of these species. Nineteen of the day-active species (34%) are colonial breeders, roughly half each in the 'Predictable' and 'Unpredictable' groups. Monitoring of such species obviously necessitates counting methods designed for and dedicated to that specific purpose. An example is the monitoring of colonial Grey Herons *Ardea cinerea*, which was the first species to be surveyed nationwide in Denmark (Weibüll 1912) and has been annually monitored since 1928 in UK (Marchant *et al.* 2004). Nocturnal species (14%) constitute a discrete set of species needing specially designed monitoring programmes such as that established in Sweden (Green *et al.* 2017).

The results from the gap analysis (Tab. 2) offer a useful basis for discussing the kind of monitoring that could and should be initiated to cover the greatest number of species in the most cost-efficient way. In this context, it will also be important to consider how well the NOVANA monitoring has been able to provide trends for the species included in this list. This depends very much on what proportion of a population lives in a given study area, i.e. those EU Bird Areas (SPAs) designated for the given species. Fig. 2 shows the number of species included in the NOVANA monitoring divided into habitat classes. It reveals that 29-40% of the species in the three habitats with most species lacking annual national monitoring are partly covered by the NOVANA monitoring.

Can we get more out of the existing data? We should also consider whether the extent of existing monitoring provides sufficient information to support their effective conservation. There are two ways to achieve a better understanding of factors acting to constrain a species in time and space. First, we can better use existing CBM information on habitat and geographical distribution of count locations to study variation in time, space and habitat. Examples of this are analyses undertaken for Corn Bunting *Emberiza calandra* by comparing population trends in six Danish regions (Fox & Heldbjerg 2008) and for specialized farmland birds in three Danish regions (Heldbjerg & Fox 2016). The CBM offers largely untapped potential to support such analyses for e.g. declining species.

Second, the use of habitat information is partly limited by the coarse habitat classifications used in the CBM programme to date. The use of each common species of nine defined habitats (Coniferous woodland, Deciduous woodland, Arable, Grassland, Heath, Dunes/Shore, Bog/Marsh, Lake and Urban) has been analysed (Larsen *et al.* 2011) to define habitat indicators (Eskildsen *et al.* 2013). These analyses show whether a species selects a specific habitat type (e.g. arable farmland), but does not indicate if and how population size and density varies between different crops or even within the denoted habitat categories. As a result, we learn little about how changes in agricultural production impacts upon the abundance of

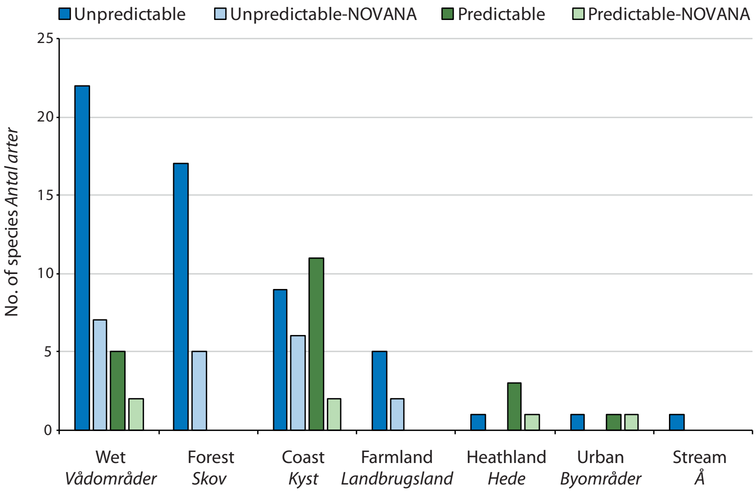

Fig. 2. Breeding habitat of 76 regular breeding Danish birds with no annual monitoring coverage at present that occur at 'Predictable' (green) as well as 'Unpredictable' (blue) breeding sites. Additional NOVANA monitoring (less than annual coverage; only Annex I species and only at sites designated for these) is included for comparison ('Predictable' (light green); 'Unpredictable' (light blue)).
Ynglehabitat for 76 danske ynglefugle uden årlig overvågning, der forekommer på 'forudsigelige' (grøn) eller 'uforudsigelige' (blå) ynglelokaliteter. NOVANA-overvågede arter er tillige vist opdelt på forudsigelige (lyst grøn) og uforudsigelige arter (lyst blå).

common farmland birds, because we cannot see, for instance, when spring cereal is converted to winter cereal or fodder beets to winter oil seed rape, and its effect on species. Inclusion of such finer-grained habitat information, based on either existing GIS information or observer recorded habitat information could be an obvious next step to improve the quality of on-site monitoring, as well as generating additional research questions and a means of answering these.

Population indices also have the potential to identify drivers of population changes by comparing several species and relating these to different traits and habitats (e.g. Heldbjerg & Fox 2008) or by summarizing and integrating monitoring results for decision makers (e.g. habitat indicators; Moshøj *et al.* 2017). Monitoring results based on multiple species, long term trends covering a large scale and producing correlative information, may create the foundation for which species/traits to include in more detailed and experimental research on a shorter term and smaller scale with the aim of finding causal relationships (e.g. Heldbjerg *et al.* 2017) and for generating hypotheses for, and testing or upscaling results from experimental research (Van Turnhout 2011).

Answers to habitat specific questions. If we are not able to capture the relevant detailed information within the existing monitoring programmes, another way of tackling this could be to establish short-term and focused projects with more narrow aims than the traditional monitoring programmes. If we could involve a large number of citizen scientists in short, well-defined and targeted projects across the country, we could obtain more detailed new information on a large scale within limited habitats. For example, we could highlight the effects of changes in the composition in mosaics of human land use in Denmark. These include the dramatic increases in the farmed area under oil seed rape or maize or the differences in bird community composition and abundance in forest patches consisting of 100-year-old trees compared to patches with 50 or 25 year-old trees. Such analyses would generate results that are of immediate use in relation to sympathetic habitat management.

Answers to demographic questions for better understanding of the observed trends. How can we improve the provision of avian demographic information? Elsewhere, nest record schemes (NRS) provide vital knowledge on clutch and brood size and are useful for understanding the variation over time and differences between regions and habitats in such metrics. This in turn provides insight into patterns of reproductive success (see above) which can potentially be built into models to predict species population trends. In the UK alone, more than 250 publications have used NRS data to describe aspects of basic breeding biology and performance, to study the population dynamics of bird populations and to investigate the demographic causes of bird population declines (Crick *et al.* 2003). Combining information from NRS with marking of adult birds for information on age of first breeding, breeding propensity and survival, can contribute knowledge about the demography of common species. The UK (Crick *et al.* 2003) and the Netherlands (Van Turnhout *et al.* 2008, SOVON 2017) have instigated coordinated programmes (such as NRS and focused ringing schemes) to measure productivity and survival to create population models to better understand the point in the annual cycle at which population limitation occurs. The potential for involving large numbers of citizen scientists in careful nest record studies (following a strict code of conduct for nest recorders; e.g. www.bto.org) is substantial for a targeted selection of species, especially if linked to ringing of parents and offspring without disturbance to either.

Integrated population model

Understanding causes of species declines requires the combination of information from several sources. In Denmark, we have a good basic understanding of species trends. Unfortunately, we can only rarely explain the ultimate drivers of these observed trends, and thus need to establish programmes that focus on delivery of these.

We will be able to better understand the demographic processes driving population changes by combining information from several sources of monitoring data to develop integrated analyses of population counts and demographic data in population models (Baillie 1990; Fig. 3). Robinson *et al.* (2014) combined abundance data from CBM with chick production and nesting success from a NRS and with survival estimates for different age classes from mark-recapture data from the Ringing Scheme. Using an integrated approach (combining datasets on different demographic parameters) allowed important demographic parameters to be identified for a number of species. Such an approach has also been used to give a better understanding of the causes of declines in breeding and migrating Wadden Sea birds (van der Jeugd *et al.* 2014).

Citizen science – potential, motivation and limits

Before embarking upon a discussion about whether we could start new, or improve existing, citizen science based monitoring programmes, we need to be convinced that there are citizen scientists willing to participate in such programmes. To understand this, we need to understand better the motivation of citizen scientists to contribute to such projects. For a large proportion of people contributing to citizen science projects, the overriding motivation is simple, namely that they find the work enjoyable (Greenwood 2007). This was confirmed by a recent Danish questionnaire (Mathiassen *et al.* 2018) completed by 434 respondents among participants of the 3rd Bird Atlas project and CBM programme. The three most important motivating factors for participation in similar potential projects was an interest in birds (95% of the answers), an interest in nature (86%), and a desire to contribute knowledge (77%). Asked for suggestions for future projects, participants varied greatly in their preferences, but most expressed interest in participating in more bird monitoring projects that had a scientific purpose and relevance for conservation.

To sustain, maintain and grow such a dedicated group of volunteers, maintenance of their interest and willingness to participate in citizen science projects is paramount. Given the c. 1470 participants in the Atlas III project, many highly motivated observers in Denmark are still willing to support such programmes. Most vol-

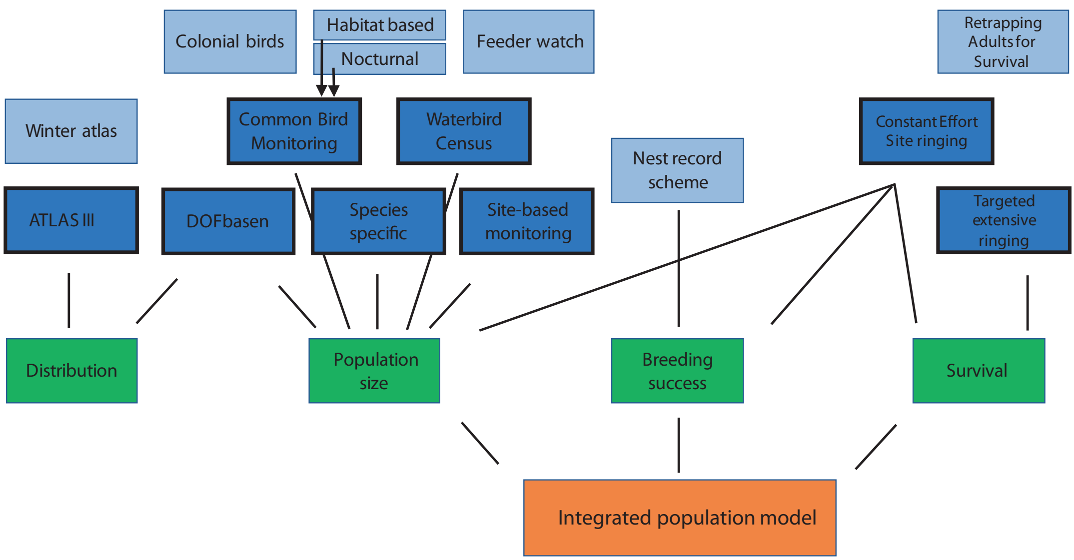

Fig. 3. Diagram showing existing (dark blue) and recommended (light blue) Danish schemes and how they could potentially contribute knowledge on the most important parameters needed to support Integrated Population Models.
Diagram, der viser eksisterende (mørkt blå) og foreslåede (lyst blå) fugleovervågningsprojekter i Danmark, og hvordan de kan bidrage til de væsentligste parametre, der er relevante for en Integreret Populationsmodel.

unteers like contributing, as long as they witness an appropriate ultimate use of their data and as long as they feel that they have the skills to apply the methods that they are asked to use.

Professional project managers must ensure that they demonstrate their gratitude, appreciation and understanding of participants. Managers need to show that participant's contributions are valued and have contributed to some clearly defined greater goal, for example by naming all participants in atlas activity. Such feedback can range from a simple thank you for the annual contribution to a statement in a scientific paper that this was only possible due to the contributions of hundreds of participants. More sophisticated interactive and personal feedback could include providing tools to display observers' own survey results in the form of graphs, maps, etc. Participants want and need to know what was discovered as a result of their efforts, and therefore have similar needs to those coordinating the work (see also Greenwood 2007). Feedback in all forms must convince most volunteers that their own relatively modest effort contributes to a far greater massive compilation of knowledge at the local, regional and/or European scale.

Danish citizen scientists are generally happy to be involved in new projects, but the limits to this involvement should be explored before initiating new projects. We may sometimes forget at our peril that these brilliant folk work for nothing apart from their own enjoyment and we should be very careful not to overexploit such incredible goodwill.

Not surprisingly, people prefer to work with simple and familiar methods, which may limit the complexity of the field activities and data reporting that volunteers are willing to contribute. For professional project coordinators, it is important to try to educate and challenge the citizen science community to use other methods. As mentioned earlier, avian density data were gathered during the 3rd Danish Bird Atlas using line transect and distance bands (Levinsky 2016). This was the first time that such methods had been proposed in Denmark and initially they were met with widespread scepticism among participants and advisors. As a result, organisers were encouraged to engage in more thorough communication and discussion both internally and with the citizen scientist community. This exchange of views led to improvements in the clarity of the goals of the project, clearer instructions and improved understanding amongst survey participants, but also, necessarily, to some weakening of the original data demands.

The observers now mostly input data themselves via apps in the field or internet portals after the fieldwork, and this task imposes yet more demands on participants but at the same time also provides opportunities to see one's own data. However, even the most skilled and dedicated participants may decide to cease their involvement if they find it too complicated to enter and upload data. For this reason, the third British Atlas project (2007-11) retained the possibility for the participants to submit data on paper as well as online (Balmer *et al.* 2013).

Involving more people in avian monitoring projects may increase the participation of less skilled observers, which may potentially affect data quality. However, survey design could potentially minimise such problems, for instance, by only surveying commoner bird species. To fulfil the ultimate scientific objective, the professional organisers will have to make sure that the contributions meet the threshold for quality assurance. The quality of the data provided by highly skilled volunteers, for instance, in CBM programmes is much higher than when involving the general public citizen scientist in projects like the garden bird projects (Meltofte & Larsen 2015), and the design of each survey must reflect the skills and experience of the expected participants.

It is also essential to combine monitoring projects with attractive outreach and education programmes to improve skills among volunteers and to educate to create a more skilled and interested community of potential citizen scientists. Dynamic, attractive and informative feedback hopefully retains more volunteers and improves their skills over time. In this way, recruits may first become engaged by participating in a less demanding project such as the Feeder Watch project and over time become involved in more demanding programmes such as the CBM (Greenwood 2007).

Conclusions and recommendations

This paper does not aim to develop a simple recipe for future monitoring of breeding birds in Denmark. Rather, we wish to create the basis for a discussion within the bird monitoring community about future directions, outlining what we can and should do in the future. In the longer term, we need to be thinking about developing more detailed strategies for involving citizen scientists in well-designed projects to enable us to reach specific goals.

Currently, relatively few organisations are involved in Danish bird monitoring. To maintain and improve avian monitoring it is essential that this relatively small community regularly discusses goals and objectives. A clear vision of precisely what is required (in relation to the available resources) is needed to adequately generate the necessary data on the distribution and abundance of all species, improve species, habitat and geographical coverage, involve new generations of observers while retaining the current network of stalwarts, and effectively integrate demographic parameters into avian monitoring in Denmark.

We should aim to identify and 'pick the low hanging fruits' through optimal use of the existing data by performing the most relevant analyses, by considering adaptations of existing monitoring schemes and by collation of existing data to achieve greater conservation aims without compromising quality or quantity. We should also consider initiating new monitoring schemes to cover missing elements in our current monitoring portfolio, e.g. species, habitats, demographic parameters, other taxa than birds, detailed and focused studies etc. We should also ensure that we generate the data we need to answer specific research questions and to enable the effective conservation and management of Danish birds in the future (Tab. 3). Decisions about the precise details of future priorities for activities must be based on discussions within the bird monitoring community and the citizen science network.

Based on the analyses presented here, we argue for the need to focus in future on monitoring the less numerous avian species of wetland, coastal and forest habitats, and that nocturnal species also need particular attention. We also urge the initiation of projects that provide information on demographic parameters, in order to support ultimately the establishment of Integrated Population Monitoring modelling that would vastly benefit from the integration of information from the different sources.

Citizen science makes an indispensable contribution to avian monitoring across the world. Photo: Sanne Busk.
Involvering af frivillige er helt uundværlig ved fugleovervågning overalt i verden.

Monitoring biologists across Europe are also working increasingly closely together in networks like BirdLife International, the European Bird Census Council and Wetlands International, which makes it easier to collaborate and to learn from each other's experiences. New Danish initiatives may find help and guidance from

Tab. 3. Overview of suggested areas to improve the monitoring of the breeding birds and winter birds in the future years with the indication of the main observer type relevant to involve for each.
Oversigt over foreslåede områder, hvorpå den danske fugleovervågning kan forbedres, og med angivelse af, hvilken type observatør, der ønskes involveret på hvert område.

Observer type *Observatørtype*	**Abundance/distribution** *Forekomst/udbredelse*	**Detailed studies** *Detaljerede studier*	**Demography** *Demografi*
Interested in birds *Fugleinteresseret*	Feeder watch *Foderbrætsundersøgelse*		Nest Record Scheme *Redeundersøgelser*
Skilled birder *Fuglekyndig*	Habitat studies *Naturtypestudier* Nocturnal species *Nataktive fugle* Colonial birds *Kolonirugere* Winter atlas *Vinteratlas*	Species-specific *Artsspecifikke studier* Communities *Fuglesamfundsstudier*	
Ringer *Ringmærker*			CES *CES* RAS *RAS*
Citizen scientist-professional interface *Citizen scientist-professionel grænseflade*		Expert facilitated collaboration *Ekspertbaseret samarbejde*	

similar, relevant programmes in neighbouring countries and thus make it easier to start and run well-designed programmes, as well as generate comparable results. Our scientific understanding only increases by broadening the scope from restricted monitoring in a small country like Denmark to look at patterns at far larger scales, such as Scandinavia or Europe.

Acknowledgements

We gratefully acknowledge the thousands of citizen scientists who have taken part in different DOF projects in the past 50 years. Thanks also to the bio-team in DOF for discussions to support the gap analysis and for help with the overall species list. We thank Chris van Turnhout, David A. Stroud and subject editor Lars Dinesen for improving the manuscript by their comments to an earlier draft and Nick Quist Nathaniels for improvement of the English. HH acknowledges the support of an industrial PhD stipend awarded by Innovationsfonden which supported this work together with the Aage V. Jensen Charity Foundation and 15. Juni Fonden.

Resumé

Hvordan kan vi forbedre fugleovervågningen i Danmark?
I overvågningen af danske fugle og dansk natur har kyndige frivillige, ulønnede deltagere altid spillet en væsentlig rolle. Dette samarbejde mellem borgere og uddannet fagpersonale omtales, selv på dansk som 'citizen science' med 'borgervidenskab' som et alternativt navn. Det er blevet den accepterede standard, at overvågning udføres ved inddragelse af citizen scientists, hvilket gør det muligt at gennemføre et stort antal registreringer på kort tid, at fortsætte undersøgelser over mange år og at holde omkostningerne tilstrækkeligt lave til at sikre gennemførelse.

Danmark har brug for overvågning for at kunne opfylde forpligtelserne i henhold til europæisk og international lovgivning og for at kunne tage de nødvendige beslutninger vedrørende forvaltning og beskyttelse af den danske natur. Desuden har organisationer som DOF og BirdLife International en stærk interesse i at kende status og udvikling for de danske fugle.

Formålet med artiklen er at tage afsæt i den tidligere og nuværende fugleovervågning for at undersøge, hvor vi kan gøre det bedre i Danmark i fremtiden. Dette præsenteres i håb om, at folk med behov for eller interesse i at kende de danske fugles status og tendenser vil blive inspireret til at skabe et grundlag for bedre fugleundersøgelser og fuglebeskyttelse i Danmark fremover, herunder at sikre en fortsat gruppe af kyndige frivillige deltagere. Heldigvis er der stadig tilstrømning af nye deltagere til DOF's projekter.

I løbet af 1960erne opstod de første store landsdækkende overvågningsprogrammer med optællinger af yngle- såvel som trækfugle på de bedste fuglelokaliteter og midvintertællinger af vandfugle. I 1970erne fulgte atlasundersøgelse og punkttællinger. Flere programmer er gennemført eller gentaget siden da, og fra 2002 fulgte DOFbasen, der skaber viden om fuglelivet i Danmark gennem hele året (Tab. 1).

Den nationale årlige overvågning af de danske fugle består nu af dels punkttællinger, der anses for tilstrækkeligt pålidelige til at levere et bestandsindeks (men ikke et bestandsestimat) for 110 arter af ynglefugle og 80 arter af vinterfugle, dels en særlig arts-fokuseret indsats for fire sjældne arter, nemlig Havørn, Hedehøg, Kongeørn og Fiskeørn, for hvilke det er muligt at registrere hvert enkelt par. Desuden gennemføres der i regi af NOVANA en overvågning, der dækker arterne på fuglebeskyttelsesområdernes udpegningsgrundlag i de fuglebeskyttelsesområder, hvor de forekommer (se Appendiks 1-3).

Danmark har stor betydning for trækkende og overvintrende fugle, men overvejelser om en forbedret overvågning af disse indgår ikke i denne artikel. Hvis vi skal lave en bedre overvågning af de danske fugle i ynglesæsonen fremover, kan vi enten inkludere flere arter eller udføre en bedre overvågning af udvalgte arter.

Blandt de 190 regelmæssige ynglefugle i Danmark er der 76 arter, der ikke indgår i den eksisterende årlige overvågning. En analyse viser, at disse arter har bestande skønnet til 1-10 000 par og således kan betegnes som sjældne og fåtallige arter (Fig. 1); nogle af disse arter er dog dækket af NOVANA-overvågningen (Fig. 2). Endvidere ses det, at de mangelfuldt dækkede arter primært findes i de tre naturtyper skov, vådområder og kyst. I sidstnævnte naturtype er 70 % ydermere kolonirugende arter. Endelig er 11 af arterne nataktive (Tab. 2). Alle disse forhold er afgørende at kende til, når man skal prioritere, hvilken målrettet indsats, der fremover skal supplere den eksisterende overvågning.

Hvis målet er at få et dybere kendskab til baggrunden for de bestandstendenser, vi ser (bestandsfremgang, -nedgang, stabilitet, fluktuation), bliver vi nødt til at inkludere demografiske parametre. Hvis en bestand ændrer sig, skyldes det ændringer i en eller flere af parametrene overlevelse, ungeproduktion og ind- og udvandring. Inkluderes studier af disse parametre, kan vi få mere viden om, *hvorfor* en bestand ændrer sig, i modsætning til i dag, hvor vi må nøjes med at konstatere, *hvor meget* den ændrer sig. For at opnå viden om disse parametre, kræves særlige indsatser som fx et rederegistreringsprojekt, men det er også muligt at bruge data fra ringmærkningsprojekter som 'Constant Effort Site'-ringmærkning (med konstant fangstindsats af ynglefugle) og anvendelse af mærknings-/aflæsningsprojekter (Fig. 3, Tab. 3). Desuden kan såvel registreringer på fuglestationer som vingeundersøgelser af nedlagte, jagtbare arter give viden om køns- og aldersfordelingen hos disse arter og således give øget viden om variationen af den årlige ungeproduktion. Vinterindsatsen kan med fordel udvides med et vinteratlas for at få bedre kendskab til arternes udbredelse og variationen i forekomsten mellem årene samt med en velovervejet have-/foderbrætsundersøgelse, der kan give detaljeret viden om arternes vinterforekomst og involvere en masse nye fugleinteresserede.

Den danske fugleovervågning udføres i samarbejde med europæiske og internationale samarbejdspartnere som BirdLife International, European Bird Census Council og Wetlands International. Eventuelle nye tiltag kan med fordel drage nytte af de erfaringer, der er opnået i andre lande. Desuden kan nogle indsatser med fordel gennemføres sammen med andre lande, så vi i fællesskab kan dække større geografiske områder og sammenligne udviklingen i de forskellige delområder.

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Appendix 1: http://dof.dk/dof/doft/2018/3.2.appendiks1
Appendix 2: http://dof.dk/dof/doft/2018/3.2.appendiks2
Appendix 3: http://dof.dk/dof/doft/2018/3.2.appendiks3

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